

NPS69-86-005

NAVAL POSTGRADUATE SCHOOL

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CONTRACTOR REPORT

THRUST VECTOR CONTROL,

HEAT TRANSFER MODELING

by

A. Leitner

"

July, 1986

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Prepared for:
Naval Postgraduate School
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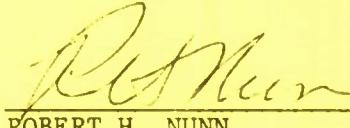
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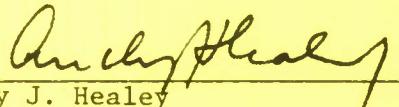

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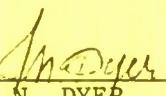

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REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b RESTRICTIVE MARKINGS										
2a SECURITY CLASSIFICATION AUTHORITY		3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.										
2b DECLASSIFICATION/DOWNGRADING SCHEDULE		4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPS69-86-005										
5a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School	6b OFFICE SYMBOL (if applicable)	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School										
6c ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000		7b. ADDRESS (City, State, and ZIP Code) Monterey, California 93943-5000										
8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Weapons Center	8b OFFICE SYMBOL (if applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N62271-86-M-0206										
8c ADDRESS (City, State, and ZIP Code) China Lake, California 93555		10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO PROJECT NO TASK NO WORK UNIT ACCESSION NO										
11 TITLE (Include Security Classification) Thrust Vector Control, Heat Transfer Modeling												
12 PERSONAL AUTHOR(S) A. Leitner												
13a TYPE OF REPORT	13b TIME COVERED FROM _____ TO _____	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT 65									
16 SUPPLEMENTARY NOTATION												
17 COSATI CODES <table border="1"><tr><th>FIELD</th><th>GROUP</th><th>SUB-GROUP</th></tr><tr><td> </td><td> </td><td> </td></tr><tr><td> </td><td> </td><td> </td></tr></table>		FIELD	GROUP	SUB-GROUP							18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
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19 ABSTRACT (Continue on reverse if necessary and identify by block number) <p>The report presents heat transfer modeling of Thrust Vector control systems using the PHOENICS computer code.</p> <p>Simple two-dimensional wedge and blunt bodies have been examined in supersonic cold flow, for both laminar and turbulent flow cases.</p> <p>The research presents a numerical solution of the supersonic compressible viscous two-dimensional flow field. Post calculations were done to estimate skin friction coefficient, surface heat flux, heat transfer coefficient and Stanton number distributions in both wedge and blunt cases.</p>												
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22a NAME OF RESPONSIBLE INDIVIDUAL		22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL									

Thrust Vector Control Heat Transfer Modeling

Abstract

The report presents heat transfer modeling of Thrust Vector control systems using the PHOENICS computer code.

Simple two-dimensional wedge and blunt bodies have been examined in supersonic cold flow, for both laminar and turbulent flow cases.

The research presents a numerical solution of the supersonic compressible viscous two-dimensional flow field. Post calculations were done to estimate skin friction coefficient, surface heat flux, heat transfer coefficient and Stanton number distributions in both wedge and blunt cases.

NOMENCLATURE

c_p	Specific heat [J/kg·k]
c_1, c_2, c_D	Constants used in turbulent model
c_f	Skin friction coefficient
h	Enthalpy [J/kg]
h_c	Heat Transfer coefficient [W/m ² k]
M	Mach number
P	Pressure
Pr	Prandtl number
q	Heat flux
R	Gas constant [J/kg·k]
Re	Reynolds number
St	Stanton number
t	Time [S]
T	Temperature

GREEK LETTER SYMBOLS

γ	Specific heat ratio
δ	Boundary layer thickness
μ	Dynamic viscosity [kg*m/s]
σ	General exchange coefficient
ρ	Density [kg/m ³]
τ_k, τ_ϵ	Constants used in turbulent model
ϕ	Any property at the grid node

SUBSCRIPTS

comp	Compressible value
eff	Effective value
inc	Incompressible value

r	Recovery
lam	Laminar quantity
t	Turbulent quantity
stat	Static values
w	Wall value
z	Local value in the flow direction
∞	Free stream value

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1. Introduction

This report describes a numerical analysis of heat transfer of a typical jet vane configuration used for thrust vector control. The work was carried out under contract Nos. N62271-85-M-0443 and N62271-86-M-0206, for the Naval Postgraduate School.

The tasks to be accomplished under the first contract were:

Task I: Formulate the conservation equations of momentum energy for two-dimensional, supersonic flow in geometries typical of thrust vector control systems.

Task II: Formulate boundary conditions for these equations appropriate to thrust vector control systems.

The tasks to be accomplished under the second contract were:

Task I: Continue and update the formulation of thrust vector control geometries based on the input from the Naval Weapons Center (NWC).

Task II: Construct the computational model for implementation in the PHOENICS code, of the thrust vector control geometries and flow conditions provided by NWC.

Task III: Run the PHOENICS code for the previously formulated models. Analyze and interpret the PHOENICS results for surface temperature and heat flux.

Thrust vector control components such as jet vanes and jet tabs are exposed to high speed hot gases at the exit of a rocket nozzle.

Estimation of the heat transfer from the hot exhaust gases to the vane is major consideration in the correct design of a vane, and its ability to survive during its mission.

The research work was done under the framework of the tasks. A brief survey of what has been done according to the task is given:

Task I (M-0443): Heat transfer modeling of thrust vector control vane requires supersonic compressible viscous flow analysis.

In order to meet the requirements, the conservation differential equations of mass momentum energy and the two $k-\epsilon$ turbulent equations were formulated, and additional algebraic formulas for the relations between pressure density and the equation of state for ideal gas.

Task II (M-0443): The physical dimensions of the flow field grid were chosen and the boundary conditions for the Navier-Stokes, energy and the two $k-q$ turbulent model equations were given.

Task I (M-0206): Working on the task, the actual configuration of a jet vane that is presently being tested at NWC has been modeled. The geometry being used is a wedge which has the same half angle and dimensions as the NWC jet vane.

Task II (M-0206): BFC (Body fitted coordinate) version of PHOENICS code (Ref. 3) was used for calculating the flow-field and heat transfer over the model. Using the BFC, a better geometrical approximation to vane shape could be achieved.

Non-Uniform grids have been utilized in order to model complicated regions in the flow field. Relaxation parameters and false timesteps options were adjusted to enable efficient computer runs with good convergence.

Task III (M-0206): In carrying out this task, four major runs have been analyzed:

Two geometric configurations were used: wedge vane and blunt vane (see Figures 1, 2, 3, 4); each one in both laminar and turbulent flow conditions.

Numerical results for fluid field and thermodynamic properties of pressure, temperature, density, Mach number and velocities are given in appendix C.

Post-calculations of heat transfer coefficient, skin friction coefficient and Stanton number are given in Figures (6, 7, 8, 9, 10, 11).

The next chapters describe in more detail the process of building the model and the analysis of the results.

2. PHOENICS Description

The present work addresses the heat transfer modeling of thrust vector control systems. In this effort the Navier-Stokes approach is applied by using a computer code which is capable of simulating a large number of fluid flow, heat transfer and chemical reaction processes which arise in industry and elsewhere. This code is called PHOENICS, which is an acronym standing for: 'Parabolic, Hyperbolic or Elliptic Numerical Integration Code Series.' The name comes from the fact that the differential equations of fluid flow, etc. arise in forms classified by mathematicians as parabolic, hyperbolic or elliptic; and PHOENICS solves these equations, whatever their form.

Built into PHOENICS are the major conservation laws of physics (mass, momentum, and energy) applied to a large number of continuous subdomains called 'cells,' into which the domain of study is artificially divided. The number of cells can be few or many according to the requirements of the problem. Because of numerical stability considerations the restrictions on cell refinement can become particularly burdensome in the calculation of a turbulent boundary layer where a very fine mesh near the wall may be required.

When supplied with appropriate information concerning: the physical properties of the materials, the geometrical and other constraints, the inlet and/or initial conditions, PHOENICS computes the corresponding solutions to the relevant differential equations, expressing them as tables of numbers describing the field of velocity, temperature concentration, etc.

Detailed information about PHOENICS is given in [Ref. 3].

2.1 The Structural Principle of PHOENICS

The code consists of three major parts: Satellite subroutine, Ground subroutine and Earth library.

The satellite subroutine is the main input subroutine and should provide the answers to the questions:

- what kind of process is to be simulated
- what are the properties of the fluid
- what are the shape and size of the domain
- how fine is the grid to be employed
- to what degree of accuracy is the calculation to be continued
- and what output should be provided

Ground subroutine is active during the computing process and is used for updating properties which vary with time, temperature, etc. For example: viscosity depends on temperature or density depends upon pressure and temperatures, etc.

Earth library is the main solver generator. It is given as a binary library and does not enable the user access to the source code.

2.2 Numerical Scheme

The numerical scheme used by the code is the simpler (semi-implicit method for pressure-linked equations revised) (Ref. 9). The scheme was developed by Patankar, S. V. and Spalding, D. B.

The scheme requires an additional dependent variable, the pressure correction, which has no physical meaning but should take part in the process.

The value of the pressure correction should tend to zero in the convergence process.

Two additional differential equations are solved: for the pressure, and for the pressure correction.

3. Geometry and Dimensions

Symmetrical 2-D planar geometry, which is shown in Figure 2, was chosen to be the approximation of the MWC vane in Figure 1.

Two geometrical profiles were examined, one with wedge leading edge and the second with blunt leading edge.

The dimensions of the domain in Figure 3 and 4 satisfy aspect ratio of 10:1 in the vertical y coordinate. A high aspect ratio in the coordinate is important for the assumption of free stream conditions at the upper boundary.

4. Assumptions

Postulating the right or the wrong assumptions has the most influence on modeling process. The stage was carried out very carefully in order to make the most compatible model with reality.

4.1 Steady state:

The modeling assumes steady state physical phenomenon process.

$$\frac{\partial}{\partial t} (\text{all properties}) = 0$$

This is a valid assumption since the time constant for the convection process is much shorter than the time constant for the wall conduction.

By assuming the wall temperature to be constant, the two procedures are decoupled.

In hot flow it is important to run the code for a wide range of wall temperature which will take into account the influence of different temperatures on the heat convection process.

4.2 Cold Air Flow

Ambient temperature air flow which was utilized by NWC experiments is being used in the computations.

4.3 Ideal Gas

The gas is assumed to satisfy the ideal gas equation of state

$$p = \rho RT \quad (4.1)$$

This is a fairly good assumption for nonreactive gas flow. In spite of the values of static temperature can decrease to 200[k], the density remain relatively low.

This assumption is an important simplification to the solution in Ref. 10 which used the isentropic relation between pressure and density instead

$$\frac{\rho}{\rho_0} = \left(\frac{P}{P_0}\right)^{1/\gamma} \quad (4.2)$$

4.4 Constant Pr,γ:

Prandtl number and γ (ratio of specific heats) were found to have negligible variations in the temperature range of the model. (200k + 350k)

4.5 Varying Viscosity and Thermal Conductivity:

μ and k are much more dependent on temperature especially very close to the solid wall where values of μ and k influence strongly the shear and heat transfer mechanism. To account for the temperature dependence power law relations have been formulated for μ and k .

$$\mu = \mu_0 \left(\frac{T}{T_0}\right)^{0.666} \quad (4.3)$$

$$k = k_0 \left(\frac{T}{T_0}\right)^{0.666} \quad (4.4)$$

4.6 Parallel Flow

Gas flow at the exit of the exhaust nozzle is more likely to be a conic source flow than parallel flow.

If the half angle of the nozzle is small, ($\alpha < 15^\circ$), parallel flow is a good assumption

4.7 Negligible Radiation

Assessments that were done showed that heat convection is at least one order of magnitude greater than heat flux by radiation.

4.8 Laminar and Turbulent Solutions

In order to overcome lack of ability to predict transition, separated laminar and turbulent calculations were done for each case. The turbulent solution utilizes the (k- ϵ) eddy viscosity model Ref. 5.

4.9 Constant Wall Temperature

The vane wall is assumed to have constant temperature during the time of calculation.

5. Governing Equations

The conservation equations for the compressible flow of the mathematical model consists of a viscous, Newtonian perfect gas consisting of the following six differential equations:

Conservation of Mass:

$$\frac{\partial}{\partial t}(\rho) + \nabla \cdot (\rho \vec{V}) = 0 \quad (5.1)$$

Conservation of momentum:

$$\frac{\partial}{\partial t}(\rho \phi) + \nabla \cdot (\rho \vec{V} \phi - \mu \nabla \phi) \cdot \nabla P = 0 \quad (5.2)$$

where ϕ is V or W velocity component for y and z direction.

Conservation of Energy

$$\frac{\partial}{\partial t}(\rho h) + \nabla \cdot (\rho \vec{V} h - \frac{\mu}{P_r} \nabla h) = \frac{Dp}{Dt} \quad (5.3)$$

where h is the total enthalpy.

$$h = C_p T_0$$

where T_0 is the total temperature

$$T_0 = T_{stat} * (1 + \frac{\gamma-1}{2} M^2)$$

In the case of laminar flow the governing equations (5.1), (5.2), (5.3) are sufficient to determine a solution when proper boundary conditions are applied and the equation of state (4.1) is provided.

Turbulence Model:

In turbulent flow it is necessary to hypothesize a turbulence model relating the turbulent viscosity to the other problem variables.

The model used in PHOENICS is the eddy viscosity ($k-\epsilon$) model [Ref. 3, Ref. 5]. In this model k , the turbulent kinetic energy and ϵ , the turbulence dissipation rate, are treated as properties of the flow and conservation equations are postulated for these properties. The two conservation equations are: one for k , the kinetic energy of turbulence:

$$\frac{Dk}{Dt} = \frac{\partial}{\partial X_j} \left(\frac{\nu_{eff}}{\sigma_k} \frac{\partial k}{\partial X_j} \right) + G_k - \epsilon \quad (5.4)$$

Second equation for ϵ , the dissipation rate of turbulence

$$\frac{D\epsilon}{Dt} = \frac{\partial}{\partial X_j} \left(\frac{\nu_{eff}}{\sigma_\epsilon} \frac{\partial \epsilon}{\partial X_j} \right) + \frac{\epsilon}{K} (C_1 G_k - C_2 \epsilon) \quad (5.5)$$

where

$$G_k = \nu_t \left(\frac{\partial \bar{U}_i}{\partial X_j} + \frac{\partial \bar{U}_j}{\partial X_i} \right) \frac{\partial \bar{U}_i}{\partial X_j} \quad (5.6)$$

$$\nu_{eff} = \nu_{lam} + \rho c_\mu k^2 / \epsilon \quad (5.7)$$

c_1 , c_2 , σ_k , σ_ϵ , c_μ are empirical constants which are provided in PHOENICS.

The reason for using the ($k-\epsilon$) model is because it is the most verified model for engineering applications. It combines simplicity, universality, and realism of predictions in most cases.

Two additional differential equations are solved also in order to satisfy the SIMPLER algorithm as was mentioned in chapter 2.2. The description of the pressure and pressure correction equations is provided by Ref. 9.

6. Input Variables

The properties of mach no. stagnation presence and temperature of the gas were provided by NWC; additional properties were taken from air tables:

Mach number:

$$M_\infty = 3.2$$

Stagnation pressure:

$$P_0 = 55 \cdot 10^5 \text{ [Pa]}$$

Stagnation temperature:

$$T_0 = 555.55 \text{ [K]}$$

Gas constant

$$R = 287. \text{ [J/kg}\cdot\text{k]}$$

Specific heat ratio

$$\gamma = 1.35$$

Laminar Prandtl Number

$$Pr = 0.7$$

Turbulent Prandtl Number

$$Pr_t = 0.9$$

Constant Pressure Specific Heat

$$C_p = R/(1-\gamma) \text{ [J/kg}\cdot\text{k]}$$

Laminar Viscosity

$$\mu = 0.1716 * 10^{-5} * (T/273.)^{0.666}$$

Thermal Conductivity

$$k = \mu C_p / Pr$$

The gas properties in the inlet boundary are equivalent to the properties at nozzle exit. Inlet properties are calculated from the stagnation values in the combustion chamber. The calculation was done by assuming one dimensional

isentropic expansion from combustion chamber to the nozzle exit (inlet for the vane).

Pressure $P_i = P_o / \left(1 + \frac{\gamma-1}{2} M^2\right)^{\gamma/(\gamma-1)}$ (6.1)

Temperature $T_i = T_o / \left(1 + \frac{\gamma-1}{2} M^2\right)$ (6.2)

Density $\rho_i = P / RT$ (6.3)

Enthalpy $h_i = C_p T_i$ (6.4)

Sonic Velocity $C_i = \sqrt{\gamma R T_i}$ (6.5)

Velocity $w_i = C \cdot M$ (6.6)

The subscript i signifies inlet property

7. Boundary Conditions

The flow field described in Figures 3, 4 has four boundaries, which can be named: inlet, outlet, freestream boundary and solid wall.

Super sonic flows have a hyperbolic mathematical nature. The field consists of influence zones, the flow at every point is governed only by its influence zone, basically by the upwind stream.

As a consequence from the discussion, it's obvious that the outlet boundary condition has no influence on the upstream flow. The boundary values that are given at the outlet are to satisfy some numerical needs only.

7.1 Inlet

Parallel uniform flow with known velocity, enthalpy, pressure, and density: equation (6.1), (6.3), (6.4), (6.6) are given at the left boundary of the grid. In PHOENICS this is specified as the LOW side of the first Z cell.

In turbulent flow, boundary conditions are supplied for k and ϵ . The values that are given are based on empirical values:

$$k_1 = 0.0 w_1^2 \quad (7.1)$$

$$\epsilon_1 = 0.16 k_1^{1.5} / (5 * GH) \quad (7.2)$$

where GH is half the vane thickness

7.2 Outlet

As was mentioned previously, the outlet has negligible effect on the results. The only property that is specified at the outlet is the pressure.

7.3 Freestream Boundary

Assuming that the upper boundary is chosen to be far enough away, the default boundary condition option of PHOENICS is used. This implies a line of symmetry where all gradients are zero.

7.4 Solid Wall

Zero velocity and constant wall enthalpy (temperature) are assumed on the wall. In PHOENICS the wall is the SOUTH side of the first y cell. The high enthalpy and velocity gradients near the wall demands a refined grid close to the wall. Values of shear stress and heat flux are calculated to first order accuracy using:

$$\tau_w = \mu \frac{\partial W}{\partial y} \approx \mu \frac{W_1}{\Delta y_1/2} \quad (7.1)$$

$$q_w = \frac{\mu}{Pr} \frac{\partial h}{\partial y} \approx \frac{\mu}{Pr} \cdot \frac{h_1 - h_w}{\Delta y_1/2} \quad (7.2)$$

In turbulent flow, a wall function is used to provide the wall condition for velocity, enthalpy, k , and ϵ

7.5 Wall Function

The wall problem in the numerical computation of flows, especially in turbulent flow, is an old one and most authors have adopted similar techniques. In effect they "bridge over" the region very close to the wall by introducing special functions which are called wall functions. These are often empirical in origin. Accounts may be found in Ref. 11.

The problem arises as follows. Turbulence dies out, close to the wall, because the no slip condition and the rigidity of the wall make all the velocity components fall to zero. The consequence is that the effective

viscosity and other transport properties fall there to their laminar values and the result is a rapid variation with distance from the wall both of the ϕ 's and of their gradients.

Where ϕ signifies general dependent variable, it is possible to compute these variations in detail, by using a computer code such as PHOENICS on two conditions:

- (i) the grid points must be packed into the region of steep gradient changes closely enough for sufficient numerical accuracy to be obtained
- (ii) the functions appearing in the turbulence model equations must properly represent the influence of local Reynolds number on turbulence.

Under the conditions above, the wall function sequences in the program act as follows:

The Reynolds number is first evaluated, based on the resultant velocity parallel to the wall, on the distance from the wall to the grid node and on density and laminar viscosity. If this Reynolds number is less than 132.25 (the value at which the laminar and turbulent wall function intersect) a laminar wall function is used. If this Reynolds number turns out to be greater than 132.25 the velocity variation is logarithmic and the corresponding shear stress coefficient is evaluated. This corresponds to the commonly used "log law" wall function. [Ref. 4]

7.6 Boundary Conditions in Phoenics

PHOENICS utilizes source terms for creating boundary conditions. The form of the source term of each dependent variable ϕ is:

$$S_\phi = ([m] + C_\phi) (V_\phi - \phi_p) \quad (7.3)$$

where: m - is mass flux source

ϕ_p - is the value of the dependent variable at point near the boundary

C_ϕ, V_ϕ - two coefficients specified by the user. The source term for

mass flux is simply

$$S_m = C_m (V_m - P_p) \quad (7.4)$$

where: P_p - is the pressure near the boundary and C_m , V_m are two coefficients.

The values of C_ϕ and V_ϕ for the dependent variables in SATELLITE are: At the

Inlet:

$$C_m = 2 \frac{\gamma}{\gamma-1} \frac{l}{W_i} \quad (7.5)$$

$$V_m = P_o \rho_i / P_o \quad (7.6)$$

$$C_w = C_h = C_k = C_\epsilon = 0. \quad (7.7)$$

$$V_w = W_i \quad (7.8)$$

$$V_h = h_i \quad (7.9)$$

$$V_k = K_i \quad (7.10)$$

$$V_\epsilon = \epsilon_i \quad (7.11)$$

At the Outlet:

$$C_m = 1000 * W_i \cdot \rho_i / P_i \quad (7.12)$$

$$V_m = P_i \quad (7.13)$$

At the Wall (laminar)

$$C_w = \mu / (0.5 \Delta \mu_1) \quad (7.14)$$

$$V_w = 0 \quad (7.15)$$

$$C_h = \mu / Pr / (0.5 \cdot \Delta \mu_1) \quad (7.16)$$

$$V_h = C_p * T_w \quad (7.17)$$

At the Wall (turbulent)

$$C_w = C_h = C_k = C_\epsilon = WALL \quad (7.18)$$

$$V_w = V_k = V_\epsilon = 0 \quad (7.19)$$

$$V_h = C_p * T_w \quad (7.20)$$

8. Mesh Generation

In this work a two-dimensional mesh is being used with 18×29 cells in the y and z coordinate respectively. A Nonuniform grid has been used for both directions. Figures 3 and 4 shows the grid in the z direction. A finer grid is used in the blunt region, $Iz = (7 \pm 17)$, and in the zone, where the inclined wall transitions to a straight wall, $Iz = (23 \pm 26)$.

In the y coordinate, except in the boundary layer region, the grid is uniform. To obtain a finer grid resolution in the boundary layer for the laminar flow case the first five cells in the y direction from the wall obey the following proportionality relationship:

$$\text{BYFRAC (IY)} = \left(\frac{\text{IY}}{5}\right)^3 \left(\frac{\Delta_{\max}}{10GH}\right) \quad (8.1)$$

Where BYFRAC(IY) is the distance from the south side to the north side of the cell of particular interest, divided by total length of the domain, IY is the cell number, Δ_{\max} is maximum allowable cell height, and GH is the half thickness of the TVC jet vane.

A fine grid resolution for the turbulent flow case is set up in the same way as laminar flow. The only difference comes from the selection of the first five cells in y direction. The following calculation shows the difference.

From the laminar solution and the given properties the following are known:

$$w = 885.2[\text{m/s}]$$

$$\mu_{\text{lam}} = 1*10^{-5} [\text{N.s/m}]$$

$$\rho_0 = 5.5*10^6 [\text{Pa}]$$

$$P_{\text{static}} = 1.048*10^5 [\text{Pa}]$$

$$\gamma = 1.35$$

$$\rho = 1.835 \text{ [kg/m]}$$

Using the values above and the length of vane, which is 0.095m, A corresponding Reynolds number was calculated:

$$Re_z = \frac{\rho_\infty W_\infty Z}{\mu_{lam}} = \frac{(1.835 * 888.5 * 0.095)}{1 * 10^{-5}} = 1.54 * 10^6$$

Using a power law correlation for the boundary layer thickness:

$$\frac{\delta}{z} = 0.37 * Re_z^{-1/5} \quad (8.2)$$

From equation (8.2) the boundary layer thickness at the high end of the domain has been calculated as $\delta \approx 2 * 10^{-3} \text{ [m]}$

With Re based on W_∞ the velocity parallel to the wall, $\frac{\Delta y}{2}$ the distance from the wall to the first grid node, ρ_∞ the density, and μ_{lam} the laminar viscosity, Δy must satisfy the condition

$$Re_\Delta = \frac{\rho_\infty W_\infty \Delta Y}{2 \mu_{lam}} > 132.25 \quad \text{or} \quad \Delta Y > 6.48 * 10^{-6} \text{ [m]}$$

Therefore the interval of Δy is chosen such that

$$2 * 10^{-3} \text{ [m]} > \Delta Y > 6.48 * 10^{-6} \text{ [m]}$$

In this effort using the relationship

$$BYFRAC(IY) = \left(\frac{IY}{5}\right)^2 \left(\frac{\Delta_{max}}{10GH}\right)$$

Δy has been calculated as $\Delta y = 8 * 10^{-5} \text{ [m]}$ which is in the required interval.

For both the laminar and turbulent cases, cells in the z direction were adjusted so that the points where possible physical phenomena such as shock waves and expansion fans are expected, very fine cells were used. In the other parts of the domain larger cells were used.

9. Heat Transfer Analysis

Skin friction and heat transfer quantities were calculated in both laminar and turbulent cases and they are shown in Figures (6 + 11).

9.1 Laminar Calculation

In laminar flow fluxes can be derived directly from the gradients near the wall. The first cell is close "enough" to the wall and gradients of velocity and enthalpy do not change much in this region near the wall. The shear stress and heat flux in the laminar case will be:

$$\tau_w \approx \mu \frac{W_1}{\Delta Y_1/2} \quad (7.1)$$

$$q_w \approx \frac{\mu}{P_r} \frac{h_1 - h_w}{\Delta Y_1/2} \quad (7.2)$$

The skin friction coefficient and Stanton number will be:

$$C_f = \frac{2 * \tau_w}{\rho_\infty W_\infty^2} \quad (9.1)$$

$$S_t = q_w / [\rho_\infty \mu_\infty (h_r - h_w)] \quad (9.2)$$

where h_r is the recovery enthalpy

$$\frac{h_r}{h_0} = \frac{1 + \frac{r(\gamma-1)}{2} \frac{M_\infty^2}{M_\infty^2}}{1 + \frac{(\gamma-1)}{2} \frac{M_\infty^2}{M_\infty^2}} \quad (9.3)$$

r - is the recovery factor

$$r = \sqrt{Pr} \quad (\text{laminar flow}) \quad (9.4)$$

The coefficient of heat transfer in convection was calculated using

$$h_c = \rho_\infty U_\infty C_p S_t \quad (9.5)$$

9.2 Turbulent Calculations

In turbulent flow the gradients of velocity and enthalpy near the wall are very steep and change rapidly with distance from the wall.

Direct calculation of flux gradients is not accurate in this case. The log law approach is used to calculate skin friction. In the calculations using PHOENICS flow field, the following relation has been used.

$$C_f = \frac{2}{w^2 \rho_\infty} \frac{k_w}{3.33} \quad (9.6)$$

To obtain equation 9.6, the turbulent kinetic energy equation has been used as a starting point. [Ref. 5],

$$\begin{aligned} \rho \frac{Dk}{Dt} &= \frac{\partial}{\partial y} \left(\frac{\mu_t}{k} \frac{\partial k}{\partial y} \right) \\ &+ k \left[\frac{\mu_t}{k} \left(\frac{\partial u^2}{\partial y} \right)_w - C_D \frac{\rho^2 k}{\mu_t} \right] \end{aligned} \quad (9.7)$$

The source term of the turbulent kinetic energy equation should be zero near the wall which means

$$\frac{\mu_t}{k} \left(\frac{\partial u}{\partial y} \right)_w^2 - C_D \frac{\rho^2 k}{\mu_t} = 0 \quad (9.8)$$

therefore the shear stress on the wall can be defined as:

$$\tau_w = C_D^{1/2} \rho_w k_w \quad (9.9)$$

where k_w is the turbulent kinetic energy on the wall, ρ_w is the density on the wall and $C_D = 0.09$ [Ref. 5], substituting the values above into the Blasius skin friction relation the C_f equation becomes:

$$C_f = \frac{2 \tau_w}{\rho_\infty W_\infty^2} = \frac{\rho_w}{\rho_\infty} \frac{2}{W_\infty^2} \frac{k_w}{3.33} \quad (9.10)$$

The heat transfer quantities are evaluated from the Chilton-Colburn form of Reynolds analogy.

$$s_t = (C_f/2) * P_r^{-2/3} \quad (9.11)$$

$$q_w = s_t * \rho_\infty * U_\infty * (h_r - h_w) \quad (9.12)$$

where equation (9.3) is used to evaluate h_r with the recovery factor given as:

$$r = P_r^{1/3} \text{ (turbulent flow)} \quad (9.13)$$

The convective heat transfer coefficient is calculated by using equation (9.5)

10. Code and Computer

PHOENICS 81, Body Fitted Coordinate (BFC) version has been used in the computations (see Ref. 3). PHOENICS has been installed on NPS IBM 3033 MVS 1.3 computer. 400 sweeps per computer run provided a reasonable convergence in all runs except the turbulent blunt case continuity error of less than $4 \cdot 10^{-4}$ has been achieved in the three runs.

The continuity error is the total summation of the absolute mass imbalance in all cells divided by the inlet mass flux. CPU time consumption varies from case to case as follows:

Laminar Wedge	630	CPU Seconds
Turbulent Wedge	630	CPU Seconds
Laminar Blunt	630	CPU Seconds
Turbulent Blunt	1542	CPU Seconds for 1000 sweeps

11. Results and Discussion

The results of the calculations are available on appendix c. The tabular results include the values of pressure, velocities, enthalpy, temperature mach number, density, turbulent kinetic energy and rate of turbulent dissipation. The values are given in 18 x 29 cells points.

Skin friction and heat transfer results are shown in Figures (5-11). Laminar and turbulent skin friction and Stanton number in wedge flow show improvement compared to the results reported by Yukselen (Ref. 10). The lines are smoother and the oscillations at the end were eliminated. Basically the magnitudes are similar to those in Ref. 10.

Laminar blunt values are similar except near the beginning. The beginning, as expected in blunt zone, creates higher rates of heat transfer. Even though the blunt geometry used is a multi-wedge shape it should predict the correct values except for the stagnation point itself.

Turbulent blunt skin friction has different behavior. It has a very large value at the first point and then undershoots to values that are smaller than for wedge. It should also be kept in mind that the convergence of this case wasn't very successful.

12. Conclusions and Recommendations

1. PHOENICS was found to be a friendly code for simulating complicated mixed heat transfer fluid dynamics problems.
2. Derivation of heat transfer properties to a vane solid wall in laminar and turbulent flow has been installed in the code. It can be used for predictions of heat transfer rate in both cold and hot gas flow.
3. Two features have been added to the code in NPS: The restart option and the use of initial field, make it possible to simulate time dependent processes and solve the temperature variation in the vane itself.

LIST OF REFERENCES

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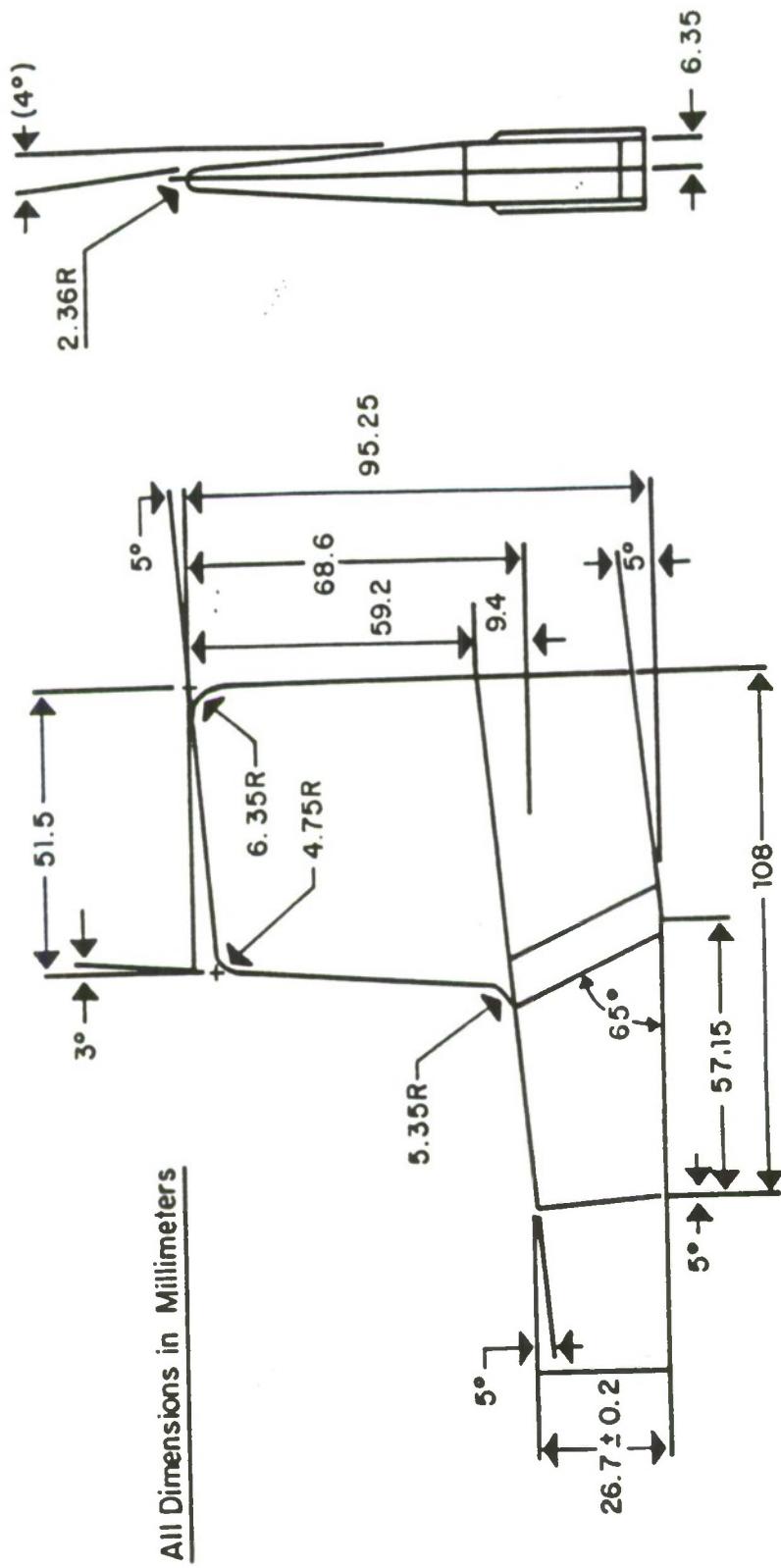


Figure 1: NWC Jet vane configuration.

All Dimensions in Millimeters

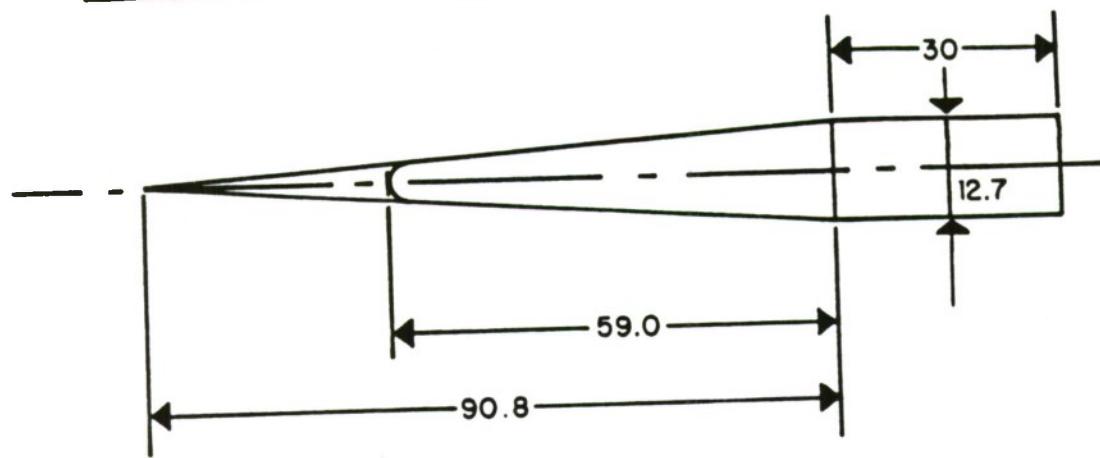


Figure 2: NWC Jet Vane Approximation

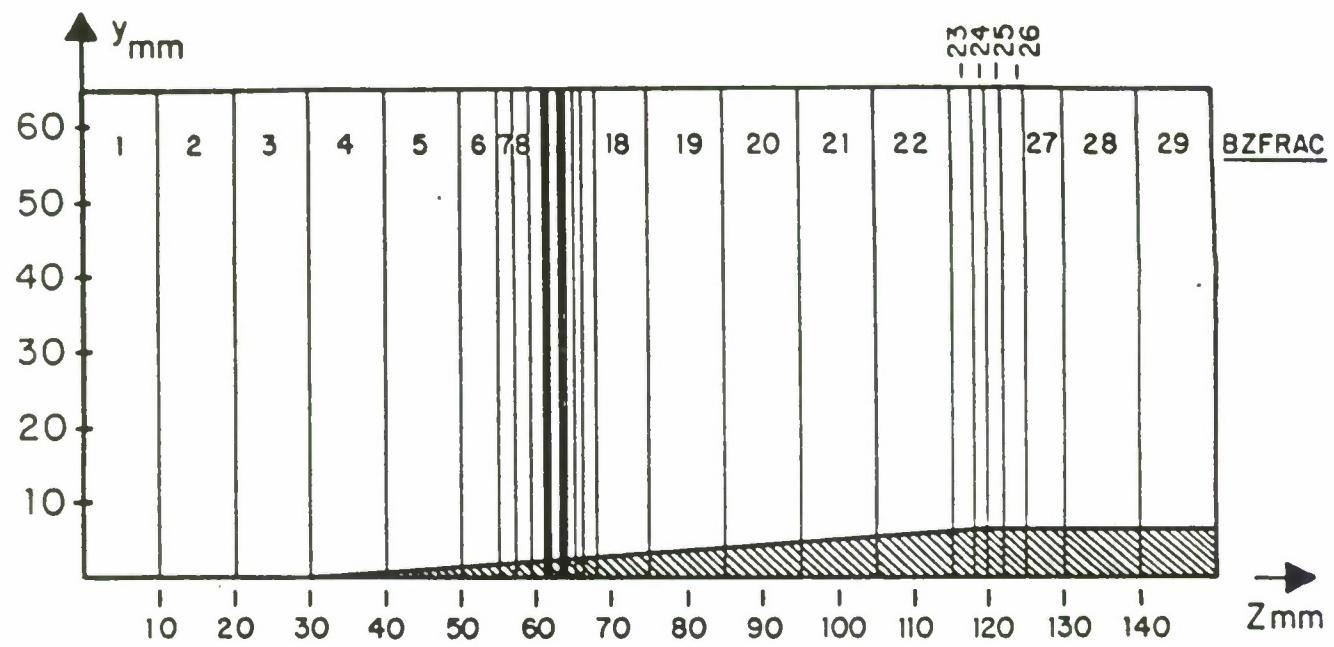


Figure 3: Wedge vane domain and grid

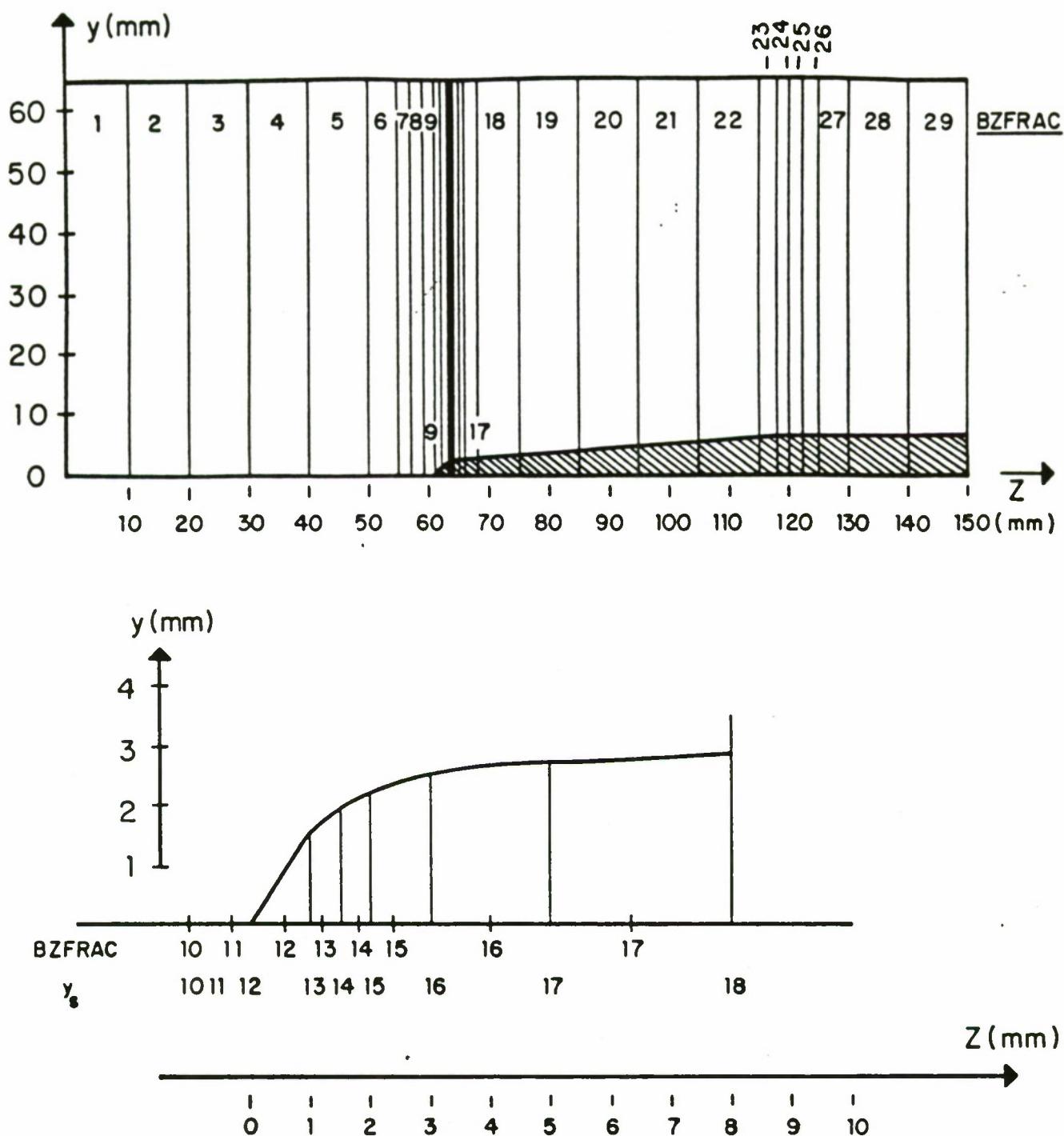


Figure 4: Blunt vane domain and grid.

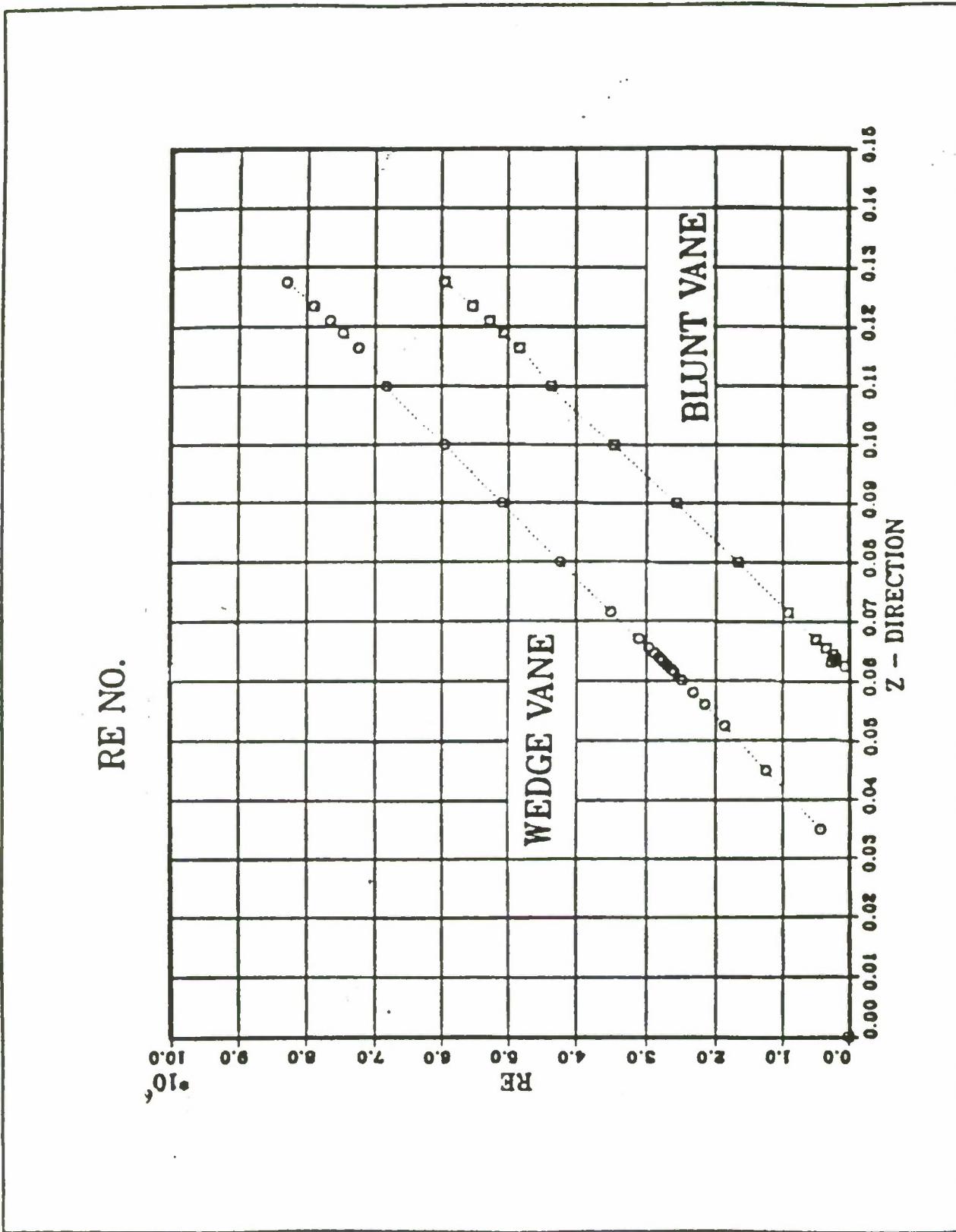


Figure 5: R_{e_x} No. along the Vane

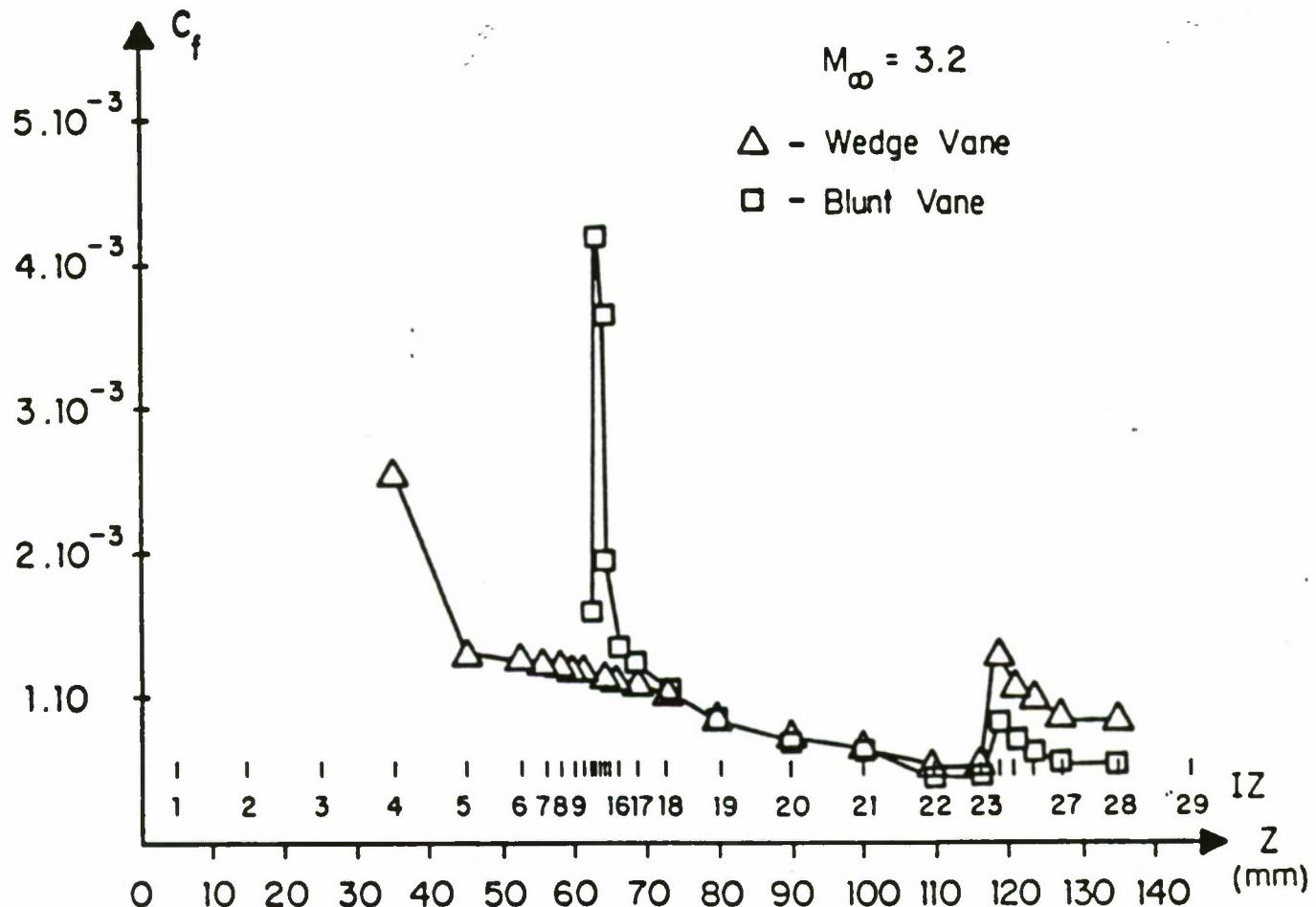


Figure 6: C_f in Laminar flow.

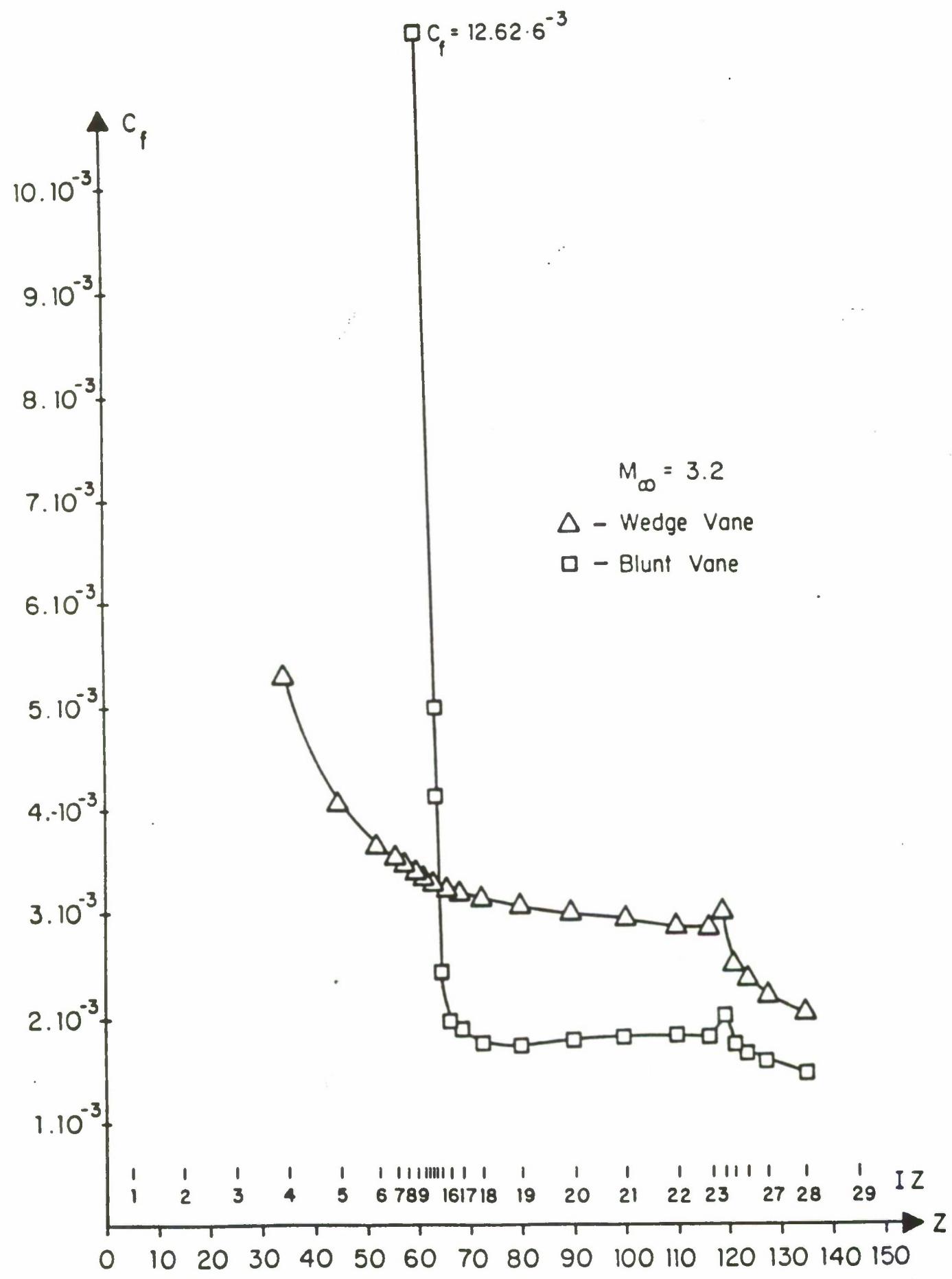


Figure 7: C_f in Turbulent flow

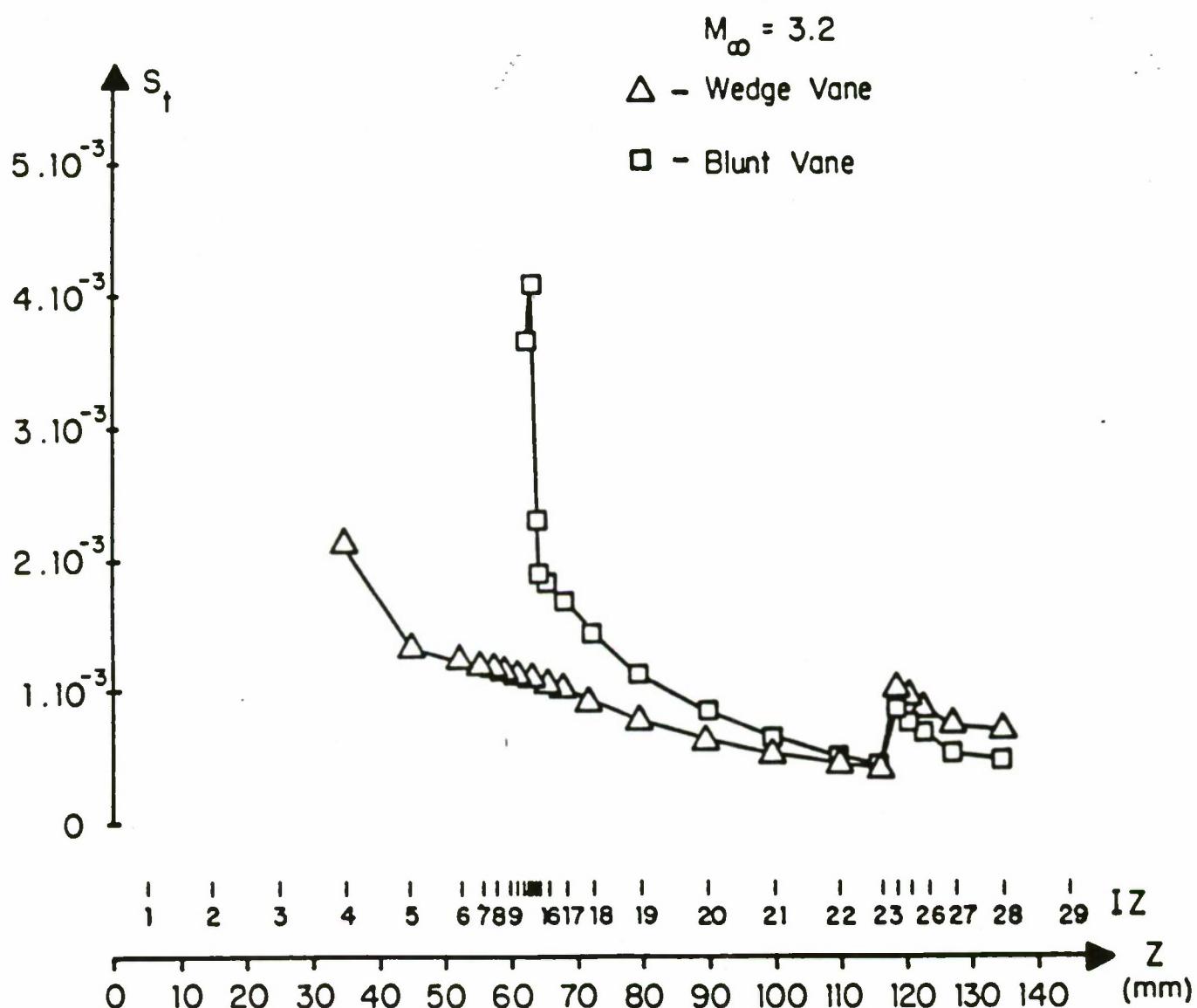


Figure 8: S_t in Laminar flow

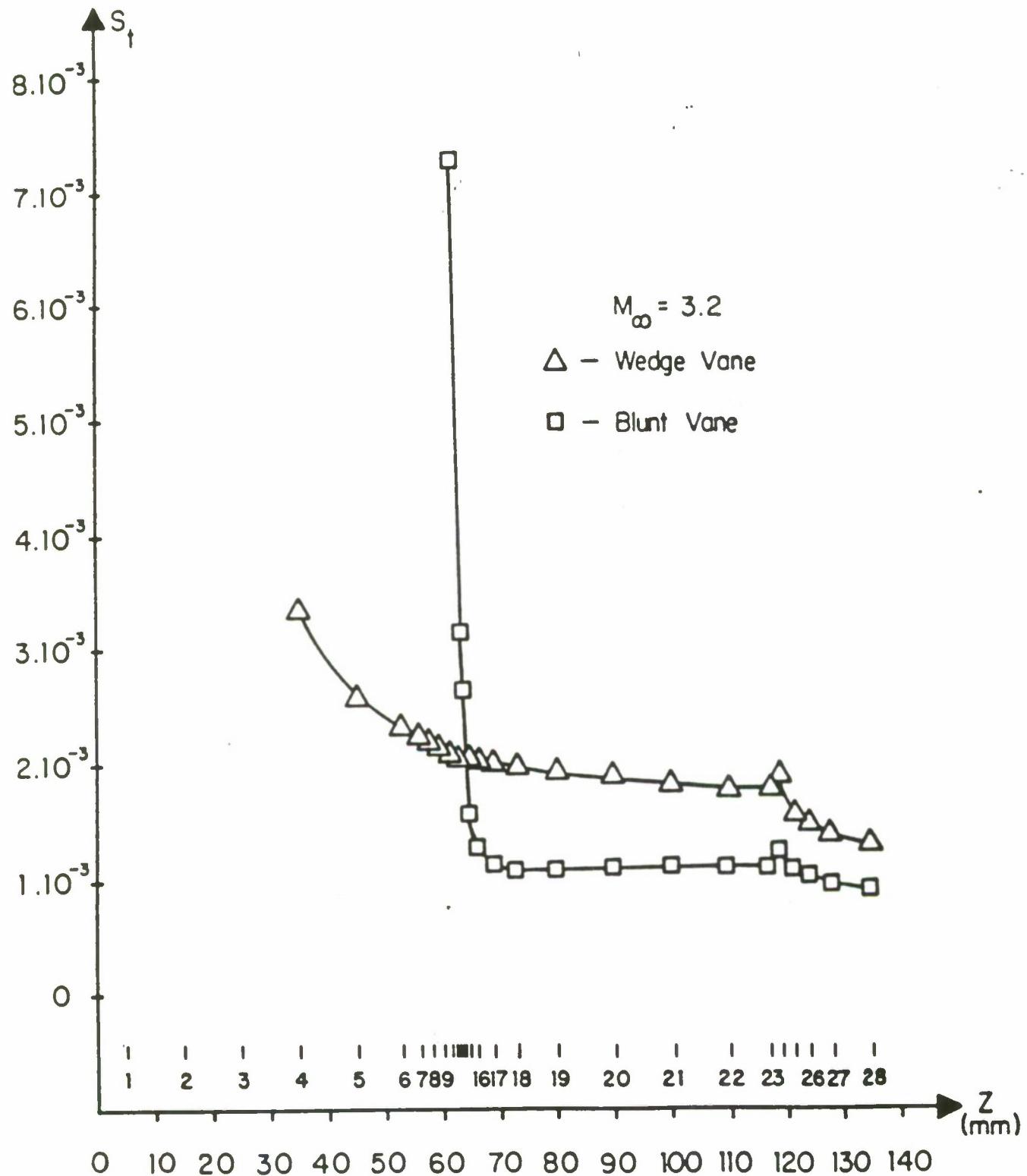


Figure 9: Turbulent stanton number.

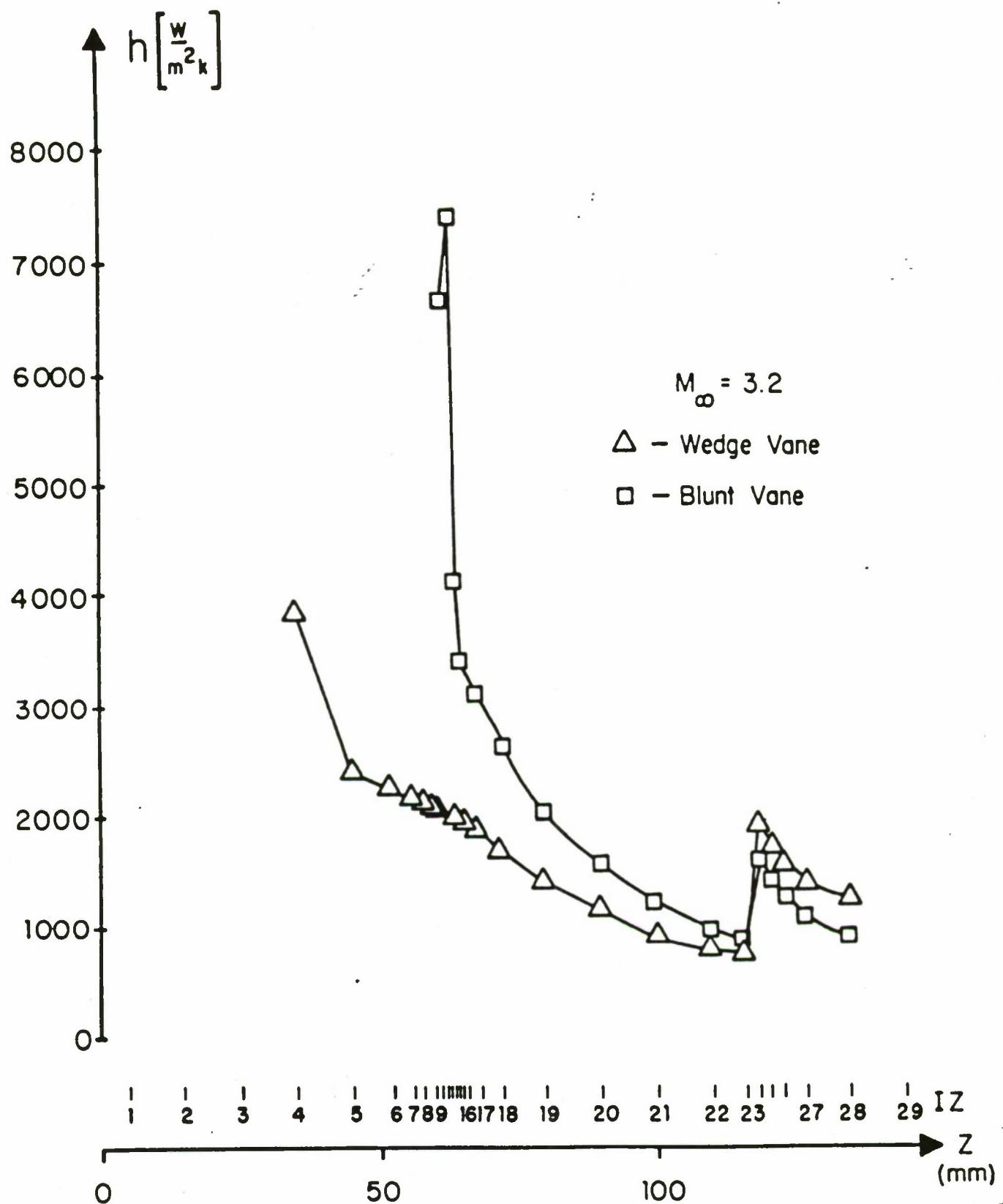


Figure 10: Coefficient of heat convection in laminar flow.

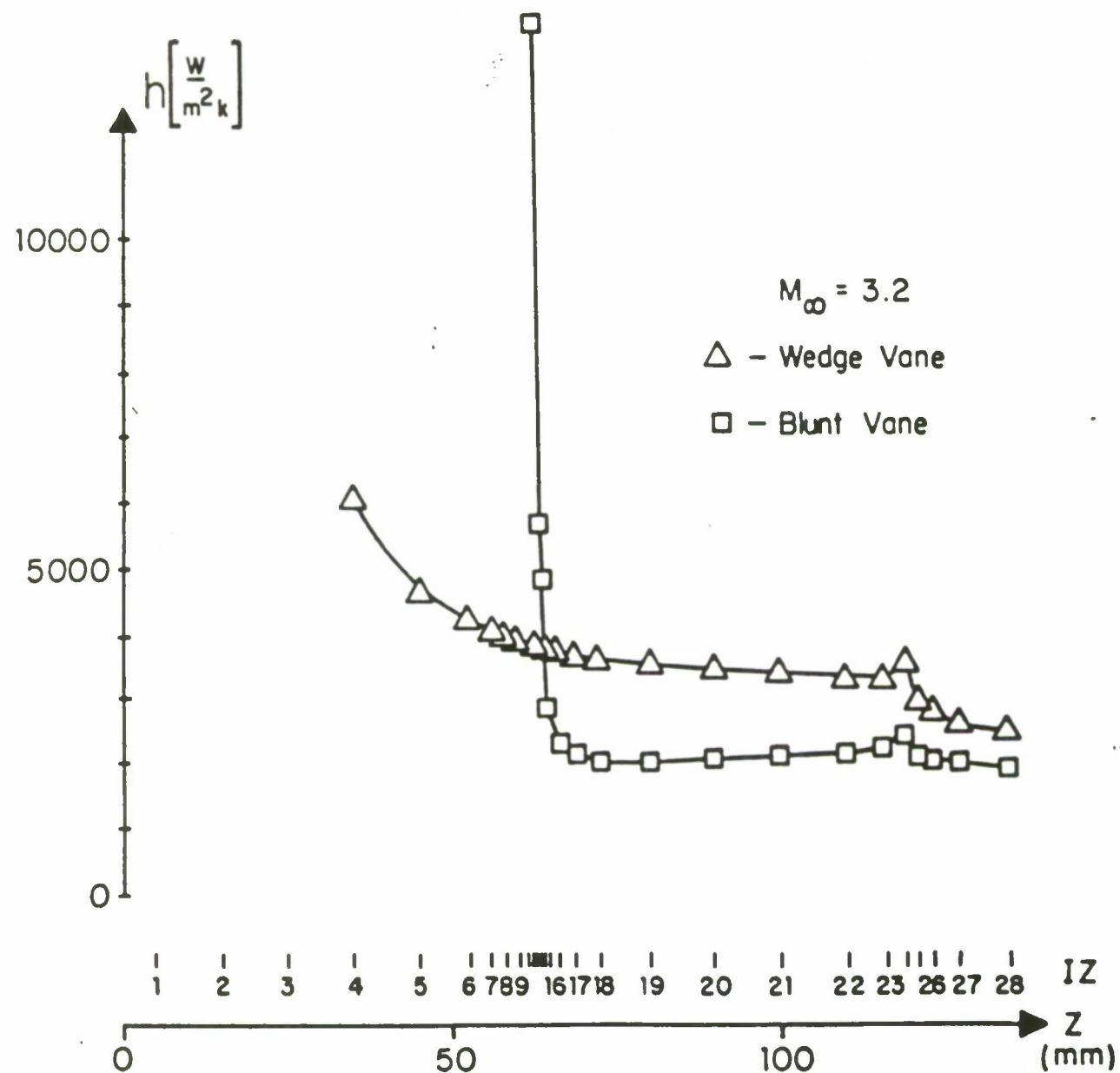


Figure 11: Coefficient of heat convection in turbulent flow.

Appendix A

Satellite Listing

Two subroutines SATELLITE and GROUND had to be changed and improved. The full list is enclosed in Appendix A and B.

VAN4SAT and VANTSAT are the laminar and turbulent SATELLITE subroutines, the first has the blunt geometry and the second has the wedge (it can be changed easily from wedge to blunt and vice versa) VAN4GRD and VANTGRD are exactly the same. They are the GROUND subroutines, VANTGRD is given in Appendix B.

FILE: VANTSAT FORTRAN A1

```

C$DIRECTIVE***SATLIT AMI LEITNER          VAN00010
C   LAMINAR SOLUTION FOR NWC5  NY=18 NZ=29 YN=GTH  VAN00020
C   LECSAT CONVERTED TO DIAMSAT  VAN00030
C   *FILE NAME: MODBFCST.FTN  VAN00040
C   *ABSTRACT: SATELLITE MODEL MAIN PROGRAM. THIS VERSION IS  VAN00050
C     FOR USE WITH THE BODY-FITTED COORDINATE SCHEME (SUMMER 1984)  VAN00060
C     VERSION) PROVIDED AS AN ATTACHMENT TO SPRING 1983 PHOENICS.  VAN00070
C   *DOCUMENTATION: PHOENICS INSTRUCTION MANUAL (SPRING 1983)  VAN00080
C     WITH BODY-FITTED COORDINATES INSTRUCTION SUPPLEMENT  VAN00090
C     (SUMMER 1984).  VAN00100
C   *AUXILIARY SUBROUTINES (TAPES, ETC.) ARE IN SATELLITE LIBRARY  VAN00110
C     SERVICEU, WHICH MUST BE INCLUDED IN LINK EDIT TO RUN.  VAN00120
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 1 STARTS:  VAN00130
C-----  VAN00140
CHAPTER 1 COMMON BLOCKS AND USER'S DATA.  VAN00150
C-----  VAN00160
INCLUDE (CMNGUS)  VAN00170
INCLUDE (CMNGRF)  VAN00180
INCLUDE (GUSSEQ)  VAN00190
COMMON/CPI/IPWRIT, IDUM(243)  VAN00200
DIMENSION GDTAPE(3), DFAULT(4)  VAN00210
DIMENSION ARRAY1(309), ARRAY2(194), ARRAY3(421)  VAN00220
LOGICAL ARRAY1, LSPDA, WRT, RD, NAMLST  VAN00230
INTEGER ARRAY2, XPLANE, YPLANE, ZPLANE  VAN00240
INTEGER P1, PP, U1, U2, V1, V2, W1, W2, R1, R2, RS, EP, H1, H2, H3, C1, C2,  VAN00250
&C3,C4  VAN00260
REAL NORTH, LOW  VAN00270
LOGICAL BFC  VAN00280
EQUIVALENCE (ARRAY1(1), CARTES), (ARRAY2(1), NX)  VAN00290
EQUIVALENCE (ARRAY3(1), SPARE1(1)), (M1, R1), (M2, R2)  VAN00300
EQUIVALENCE (LSTRUN, INTGR(12)), (NAMLST, LOGIC(88))  VAN00310
EQUIVALENCE (LOGIC(20), BFC)  VAN00320
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 1 ENDS.  VAN00330
C$DIRECTIVE***CMNBF1$$  VAN00340
C   THIS FILE CONTAINS SATELLITE COMMON BLOCKS FOR BFC'S  VAN00350
C   F1 MUST BE DIMENSIONED TO GREATER THAN OR EQUAL TO  VAN00360
C   (NX+NY+17*NZ+24*NX*NY+6*(NX+1)*(NY+1)+6*ND). THE VALUE  VAN00370
C   OF THE DIMENSION MUST BE SET AS NBFC IN GROUP 6 OF SATLIT.  VAN00380
COMMON/FOB/F1(5000)  VAN00390
COMMON/CIB/ND/CIC/KOORD  VAN00400
COMMON/CID/KDBGG, KDBGMF, KDBGCD, KDBIND, KDBMFX, KDBCCT, KDBPCS,  VAN00410
&      KDBGUW, KDBGPV  VAN00420
COMMON/CIE/KDBGS, KDBINS  VAN00430
COMMON/CIF/IGEN/CIG/NCART  VAN00440
C   THE FOLLOWING ARRAYS MUST BE EXACTLY DIMENSIONED FOR NXPI,  VAN00450
C   NYP1 AND NZP1, BUT MAY BE OVER DIMENSIONED FOR ND.  VAN00460
C   THE BFRAC ARRAYS MUST BE DIMENSIONED TO ALLOW FOR SETTINGS  VAN00470
C   IN SATLIT, THEY MAY BE OVER DIMENSIONED.  VAN00480
COMMON/CRA/XH(19,30,1)/CRB/XE(19,30,1)  VAN00490
& /CRC/YS(2,30,1)/CRD/YN(2,30,1)  VAN00500
& /CRE/ZL(2,19,1)/CRF/ZH(2,19,1)  VAN00510
& /CRG/RCON/CRH/DARCY/CRI/BXFRAC(99)/CRJ/BYFRAC(99)  VAN00520
& /CRK/BZFRAC(99)  VAN00530
COMMON/CLA/STORSA(6), STORWD(6), STORP, STORPE, STORPN,  VAN00540
&      STORPH, STOR1, STOR2, STOR3, STOUNV, PRTBFC, STOCRN  VAN00550
COMMON/CLC/BFPLOT  VAN00560
LOGICAL STORP, STORPE, STORPN, STORPH, STOR1, STOR2, STOR3,  VAN00570
&      STORSA, STORWD, STOUNV, PRTBFC, BFPLOT, STOCRN  VAN00580
C   END  VAN00590
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 1 STARTS:  VAN00600
C   GRAFFIC ARRAYS DIMENSIONED AS NEEDED...  VAN00610
COMMON/GRAF1/PHI1(1) /GRAF2/PHI2(1)  VAN00620
C   POROSITY & SPECIAL DATA ARRAYS DIMENSIONED AS NEEDED...  VAN00630
DIMENSION PE(1,1,1), PN(1,1,1), PH(1,1,1), PC(1,1,1)  VAN00640
DIMENSION LSPDA(1), ISPDA(1), RSPDA(1)  VAN00650
C   USER PLACES HIS VARIABLES, ARRAYS, EQUIVALENCES ETC. HERE.  VAN00660
EQUIVALENCE(RAIR, RE(21)), (GAMA, RE(22)), (GSWP, RE(23))  VAN00670
1, (GPR, RE(24)), (TW, RE(25)), (GEMU1, RE(26)), (JEMU1, INTGR(1))  VAN00680
C   USER PLACES HIS DATA STATEMENTS HERE.  VAN00690
DATA NLSP, NISP, NRSP/1,1,1/  VAN00700
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 1 ENDS.  VAN00710
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 2 STARTS:  VAN00720

```

```

C-----  

C CHAPTER 2 SET CONSTANTS, AND ARRANGE FILE MANIPULATIONS.-----  

C-----  

C PLEASE DO NOT ALTER, OR RE-SET, ANY OF THE REMAINING  

C STATEMENTS OF THIS CHAPTER.  

C DATA CELL,EAST,WEST,NORTH,SOUTH,HIGH,LOW,VOLUME/  

& 0.,1.,2.,3.,4.,5.,6.,7./  

C DATA P1,PP,U1,U2,V1,V2,W1,W2,R1,R2,RS,KE,EP,H1,H2,H3,C1,C2,  

& C3,C4/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20/  

C DATA FIXFLU,FIXVAL,ONLYMS,WALL/1.E-10,1.E10,0.0,-10.0/  

C DATA IPLANE,XPLANE,YPLANE,ZPLANE/0,1,2,3/  

C DATA WRT,RD,DEFAULT/.TRUE../.FALSE./,4HDEFA,4HULT.,,4HDTA/,1HG/  

C DATA GDTAPE/4HGUSI,4HE1.D,2HTA/  

C DATA NLDATA,NIDATA,NRDATA/309,194,421/  

C DATA NLCREG,NTCVRG/60,350/  

C DATA TITPP,TITC1,TITC2,TITC3/3HRHO,4HMACH,4HTEMP,4HCFST/  

C CALL TAPES(10,GDTAPE,3,1,4*NRDATA)  

C-----  

C-----READ DEFAULT FILE IF BLOCKDATA ABSENT  

C-----  

C IF(INTGR1(29).NE.10) GO TO 2  

C CALL WRIT40(40HDATA ESTABLISHED IN BLOCK DATA. )  

C GO TO 3  

C 2 CALL DEFLT  

CD 2 CALL TAPES(1,DEFAULT,4,2,4*NRDATA)  

CD CALL DATAIO(RD,1)  

CALL WRIT40(40HDATA TAKEN FROM DEFAULT.DTA ON GROUP A/C)  

3 CALL WRIT40(40HFILE MODSTL.FTN IS THE SATLIT USED. )  

LOGIC(89)=.TRUE.  

C-----  

C-----CHAPTER 3 DEFINE DATA FOR NRUN RUNS.  

C-----  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 2 ENDS.  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 2 STARTS:  

C--- GROUP 41MULTI-RUNS : RUN(1-30)<.T.,29*.F.>  

C  

C RUN(1)=.FALSE.  

C NOTE: ALL RUNS ARE DEACTIVATED AT THIS POINT - USER SHOULD  

C === SWITCH ON ONE ONLY OF RUNS 1-4 IN NEXT STATEMENT.  

RUN(1)=.TRUE.  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 2 ENDS.  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 3 STARTS:  

DO 10 IRUN=1,30  

IF(.NOT.RUN(IRUN)) GO TO 10  

NRUN=NRUN+1  

LSTRUN=IRUN  

10 CONTINUE  

DO 999 IRUN=1,LSTRUN  

IF(.NOT.RUN(IRUN)) GO TO 999  

INTGR(1) = IRUN  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 3 ENDS.  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 3 STARTS:  

C--- ALL INTEGER VARIABLES ARE DEFAULTED TO 0, AND REAL VARIABLES  

C TO 0.0, UNLESS OTHERWISE INDICATED.  

C E.G. BY VARIABLE<10>, OR <10.0> AS APPROPRIATE.  

C THE DEFAULT SETTINGS OF ALL LOGICAL VARIABLES ARE ALWAYS  

C INDICATED, E.G. VARIABLE<.T.>, OR VARIABLE<.F.>.  

C  

C--- RUN1  

C-----  

C--- GROUP 1. FLOW TYPE :  

C PARAB<.F.>,CARTES<.T.>,ONEPHS<.T.>  

C-----  

C--- GROUP 2. TRANSIENCE :  

C STEADY<.T.>,ATIME,LSTEP<1>,FSTEP<1>  

C TLAST<1.E10>,TFRAC(1-30)<30*1.>  

C SERVICE SUBROUTINE FOR 'NT' POWER-LAW TIME STEPS:  

C CALL GRDPWR(0,NT,TLAST,POWER)  

C-----  

C--- GROUP 3. X-DIRECTION :  

C NX<1>,XULAST<1.0>,XFRAC(1-30)  

C SERVICE SUBROUTINE FOR POWER-LAW GRID:  

C CALL GRDPWR(1,NX,XULAST,POWER)  

C-----  


```

```

C--- GROUP 4. Y-DIRECTION :
C   NY<1>,YVLAST<1.0>,YFRAC(1-30),RINNER,SNALFA           VAN01450
C   SERVICE SUBROUTINE FOR POWER-LAW GRID:                      VAN01460
C   CALL GRDPWR(2,NY,YVLAST,POWER)                                VAN01470
C   NY=18                                                       VAN01480
C-----                                         -----
C--- GROUP 5. Z-DIRECTION :
C   NZ<1>,ZWLAST<1.0>,ZFRAC(1-30)                         VAN01490
C   SERVICE SUBROUTINE FOR POWER-LAW GRID:                      VAN01500
C   CALL GRDPWR(3,NZ,ZWLAST,POWER)                                VAN01510
C   NZ=29                                                       VAN01520
C-----                                         -----
C--- GROUP 6. MOVING GRID OR DISTORTED (BODY-FITTED) GRID :
C   --- MOVING GRID :                                         VAN01530
C   MGRID,IZW1,IZW2,AZW2,BZW2,CZW2,PINT,ZW2M1T                VAN01540
C-----                                         -----
C   --- BODY-FITTED GRID ---                                     VAN01550
C   BFC<.T.>,IGEN<1>,ND<1>,NBFC<5000>,KOORD,RCON          VAN01560
C   BXFRAC(1-NX)<1.0,NXM1*x0.0>                                VAN01570
C   BYFRAC(1-NY)<1.0,NYM1*x0.0>                                VAN01580
C   BZFRAC(1-NZ)<1.0,NZM1*x0.0>                                VAN01590
C   SERVICE SUBROUTINE FOR SUB-DOMAIN SPECIFICATION (FOR IGEN=1    VAN01600
C ONLY):                                                 VAN01610
C   CALL DOMAIN(ID,IXF,IXL,IYF,IYL,IZF,IZL)                      VAN01620
C   XE(1-NYP1,1-NZP1,1-ND)<(NYP1*NZP1*ND)*1.0>,               VAN01630
C   XW(1-NYP1,1-NZP1,1-ND),                                         VAN01640
C   YN(1-NXP1,1-NZP1,1-ND)<(NXP1*NZP1*ND)*1.0>,               VAN01650
C   YS(1-NXP1,1-NZP1,1-ND),                                         VAN01660
C   ZH(1-NXP1,1-NYP1,1-ND)<(NXP1*NYP1*ND)*1.0>,               VAN01670
C   ZL(1-NXP1,1-NYP1,1-ND),STORSA(1-6)<6*x.F.>,STORWD(1-6)<6*x.F.>,    VAN01680
C   STORP<.F.>,STORPE<.F.>,STORPN<.F.>,STORPH<.F.>,STOUNV<.F.>,    VAN01690
C   PRTBFC<.F.>,DARCY,BFPLOT<.F.>                                VAN01700
C   CYCLIC BOUNDARY CONDITIONS ARE DEFAULTED INACTIVE ;          VAN01710
C   TO ACTIVATE THEM AT SELECTED IZ SLABS USE SERVICE SUBROUTINE:    VAN01720
C   CALL XCYIZ(IZ,TRUE.)                                         VAN01730
C   SERVICE SUBROUTINE TO DEACTIVATE CURVATURE TERMS IN U, V      VAN01740
C   AND W EQUATIONS ASSOCIATED WITH CURVATURE OF IX, IY, IZ        VAN01750
C   GRID LINES RESPECTIVELY:                                         VAN01760
C   CALL UCURVE(IZ,.FALSE.)                                       VAN01770
C   CALL VCURVE(IZ,.FALSE.)                                       VAN01780
C   CALL WCURVE(IZ,.FALSE.)                                       VAN01790
C   NCART<1>                                         VAN01800
C   *WARNINGS|||||||                                         VAN01810
C-----                                         -----
C   A) WHEN USING BFCS STOVAR(H3), STOVAR(C4), STOVAR(21) ARE     VAN01820
C      AVAILABLE ONLY FOR STORING NON-ORTHOGONAL VELOCITY         VAN01830
C      COMPONENTS.                                              VAN01840
C   B) MULTI-RUNS ARE NOT ALLOWED WITH BFC OPTION.                 VAN01850
C   C) MOVING GRID, TWO-PHASE AND PARABOLIC OPTIONS ARE NOT       VAN01860
C      AVAILABLE WITH BFC OPTION.                                 VAN01870
C   D) KE-EP TURBULENCE MODEL SHOULD BE USED WITH BFC'S ONLY       VAN01880
C      WHEN THE MAIN FLOW IS IN THE IZ DIRECTION.                  VAN01890
C   E) BUILT-IN GRAVITY TERMS DO NOT TAKE ACCOUNT OF BFC'S.       VAN01900
C-----                                         -----
C   *NOTES                                         VAN01910
C-----                                         -----
C   A) THE STANDARD VELOCITY-FIELD PRINTOUT FOR THE             VAN01920
C      VELOCITY RESOLUTES IS ACTIVATED IN THE USUAL              VAN01930
C      WAY. AN ADDITIONAL OPTION EXISTS FOR PRINTING THE        VAN01940
C      CARTESIAN VELOCITY-COMPONENTS WHICH MAY BE               VAN01950
C      ACTIVATED BY SETTING THE FOLLOWING LOGICALS:            VAN01960
C      STOVAR(U2)=.T. FOR U-COMPONENT (CARTESIAN)             VAN01970
C      STOVAR(V2)=.T. FOR V-COMPONENT (CARTESIAN)             VAN01980
C      STOVAR(W2)=.T. FOR W-COMPONENT (CARTESIAN)             VAN01990
C      SIMILARLY PRINTOUT OF NON-ORTHOGONAL VELOCITY          VAN02000
C      COMPONENTS MAY BE ACTIVATED AS FOLLOWS:                 VAN02010
C      STOVAR(C4)=.T. FOR U-COMPONENT (NON-ORTHOG)            VAN02020
C      STOVAR(H3)=.T. FOR V-COMPONENT (NON-ORTHOG)            VAN02030
C      STOVAR(21)=.T. FOR W-COMPONENT (NON-ORTHOG)            VAN02040
C-----                                         -----
C   B) BFC (TO ACTIVATE THE BFC OPTION), IGEN (THE CODE FOR METHOD    VAN02050
C      OF GRID SPECIFICATION), ND (NUMBER OF SUB-DOMAINS) AND      VAN02060
C      NBFC (THE F1 ARRAY DIMENSION), MUST BE SET BEFORE          VAN02070
C      "STANDARD BFC SECTION 2".                               ======    VAN02080
C

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C           ALL OTHER BFC DATA MUST BE SET AFTER "STANDARD BFC      VAN02170
C           SECTION 2.          ======      VAN02180
C           C) NXP1, NYPI, NZP1 STORE NX+1, NY+1, NZ+1; THESE ARE      VAN02190
C           AVAILABLE TO USER AFTER STANDARD BFC SECTION 2.      VAN02200
C           D) FOR IGEN=1 USE BXFRAC,BYFRAC & BZFRAC IN PLACE OF      VAN02210
C           XFRAC,YFRAC & ZFRAC.      VAN02220
C-----      VAN02230
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 1 STARTS:      VAN02240
C           DEFAULT SETTINGS:      VAN02250
C           NCART=10      VAN02260
C           BFC=.TRUE.      VAN02270
C           IGEN=1      VAN02280
C           ND=1      VAN02290
C           NBFC=5000      VAN02300
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 1 ENDS.:      VAN02310
C           *USER SETS BFC, IGEN, ND AND NBFC HERE.      VAN02320
C-----      VAN02330
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 2 STARTS:      VAN02340
C           CALL SB4I(NXP1,NX+1,NYP1,NY+1,NZP1,NZ+1,I,0)      VAN02350
C           IF(BFC) CALL BFCDFT(NBFC,XE,XW,YN,YS,ZH,ZL,ND,NXP1,NYP1,      VAN02360
C           &          NZP1,NZ)      VAN02370
CXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 2 ENDS.      VAN02380
C           *USER SETS ALL OTHER BFC VARIABLES HERE:      VAN02390
C           *USING NONIFORM GRID 1-8      VAN02400
C           GTH=65.E-3      VAN02410
C           GTL=150.E-3      VAN02420
C           GBETA=4.      VAN02430
C           GBETA=GBETA*3.1415927/180      VAN02440
C           GTAB=TAN(GBETA)      VAN02450
C           DELMAX=2.E-3      VAN02460
C           GNBL=5.      VAN02470
C           GPWR=2.      VAN02480
C           DO 64 IY=1,5      VAN02490
C           BYFRAC(IY)=(FLOAT(IY)/GNBL)*GPWR*DELMAX/GTH      VAN02500
C           BYFRAC(6)=BYFRAC(5)+3.E-3/GTH      VAN02510
C           DEL=(1.-BYFRAC(6))/(FLOAT(NY)-GNBL-1)      VAN02520
C           DO 65 IY=7,NY      VAN02530
C           BYFRAC(IY)=BYFRAC(IY-1)+DEL      VAN02540
C-----ZZ-----      VAN02550
C           BZFRAC(1)=10.E-3      VAN02560
C           DO 66 IZ=2,5      VAN02570
C           BZFRAC(IZ)=10.E-3+BZFRAC(IZ-1)      VAN02580
C           BZFRAC(6)=BZFRAC(5)+5.E-3      VAN02590
C           DO 67 IZ=7,9      VAN02600
C           BZFRAC(IZ)=BZFRAC(IZ-1)+2.E-3      VAN02610
C           DO 68 IZ=10,10      VAN02620
C           BZFRAC(IZ)=BZFRAC(IZ-1)+1.E-3      VAN02630
C           DO 77 IZ=11,14      VAN02640
C           BZFRAC(IZ)=BZFRAC(IZ-1)+.5E-3      VAN02650
C           DO 78 IZ=15,15      VAN02660
C           BZFRAC(IZ)=BZFRAC(IZ-1)+1.E-3      VAN02670
C           BZFRAC(16)=BZFRAC(15)+2.E-3      VAN02680
C           BZFRAC(17)=BZFRAC(16)+3.E-3      VAN02690
C           BZFRAC(18)=BZFRAC(17)+5.E-3      VAN02700
C           DO 69 IZ=19,22      VAN02710
C           BZFRAC(IZ)=BZFRAC(IZ-1)+10.E-3      VAN02720
C           BZFRAC(23)=BZFRAC(22)+3.E-3      VAN02730
C           BZFRAC(24)=BZFRAC(23)+2.E-3      VAN02740
C           BZFRAC(25)=BZFRAC(24)+2.E-3      VAN02750
C           BZFRAC(26)=BZFRAC(25)+3.E-3      VAN02760
C           BZFRAC(27)=BZFRAC(26)+5.E-3      VAN02770
C           DO 71 IZ=28,NZ      VAN02780
C           BZFRAC(IZ)=BZFRAC(IZ-1)+10.E-3      VAN02790
C           DO 72 IZ=1,NZ      VAN02800
C           BZFRAC(IZ)=BZFRAC(IZ)/GTL      VAN02810
C           CALL DOMAIN(1,1,NX,1,NY,1,NZ)      VAN02820
C           DO 61 IX=1,NXP1      VAN02830
C           DO 62 IY=1,NYP1      VAN02840
C           ZL(IX,IY,1)=0.0      VAN02850
C           ZH(IX,IY,1)=GTL      VAN02860
C           DO 63 IZ=1,NZP1      VAN02870
C           YN(IX,IZ,1)=GTH      VAN02880

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63 YS(IX,IZ,1)=0.0
C YS(IX,13,1) SHOULD COME AFTER
DO 662 IZ=16,25
CCC DO 662 IZ=5,25
662 YS(IX,IZ,1)=(BZFRAC(IZ-1)-BZFRAC(3))*GTAB*GTL
DO 663 IZ=13,15
GZ12=(BZFRAC(IZ-1)-BZFRAC(11))*GTL
663 YS(IX,IZ,1)=SQRT(YS(IX,16,1)*GZ12*2.-GZ12**2)
DO 664 IZ=26,NZ
664 YS(IX,IZ,1)=YS(IX,25,1)
61 CONTINUE
STORSA(IFIX(LOW))=.TRUE.
STORSA(IFIX(HIGH))=.TRUE.
STORSA(IFIX(SOUTH))=.TRUE.
STORWD(IFIX(SOUTH))=.TRUE.
STORP=.TRUE.
PRTBFC=.TRUE.
CDAR DARCY=1.E10
C-----
C--- GROUP 7. BLOCKAGE: BLOCK<.F.>,IPLANE,IPWRIT
C *SET CONSTANT POROSITIES OVER SUB-DOMAINS USING:
C CALL CONPOR(IR,TYPE,VALUE,IXF,IXL,IYF,IYL,IZF,IZL), WHERE:
C IR=RUN SECTION NUMBER, E.G. 1 FOR RUN1 SECTION; 'TYPE'= EAST,
C WEST, NORTH, SOUTH, HIGH, LOW & CELL. 'VALUE'=WANTED POROSITY
C OVER REGION IXF,...IZL.
C *DIMENSION ARRAYS PE(NX,NY,NZ), PN(NX,NY,NZ), PH(NX,NY,NZ), &
C PC(NX,NY,NZ) ABOVE.
C *FOR FULLY-BLOCKED CELLS (IE. 'VALUE'= 0.0) USER NEED SET ONLY
C THE 'CELL' POROSITY (TO ZERO), AS CELL-FACE AREAS ARE THEN
C AUTOMATICALLY ZEROED.
C *FOR SATELLITE PRINTOUT OF ALL POROSITIES IN DOMAIN, 'IPLANE'=
C XPLANE YPLANE OR ZPLANE, FOR DESIRED CROSS-SECTION DIRECTION.
C *FOR EACH 'TYPE' A MAXIMUM OF 10 CALLS TO CONPOR IS ALLOWED,
C BUT IF REQUIREMENTS EXCEED THIS PROVISION SET BLOCK=.T. &
C IPWRIT=-1, AND SET POROSITY ARRAYS EXPLICITLY HERE AS WANTED.
C IN THIS CASE, THE USER M U S T SET A L L ELEMENTS OF
C ARRAYS PE, PN, PH, PC (MANY MAY BE 0.0 OR 1.0). HE MAY USE:
C CALL CR(PARRAY,VALUE,IXF,IXL,IYF,IYL,IZF,IZL,NX,NY,NZ)
C ANY NUMBER OF TIMES, TO SET 'PARRAY' (= PE, ETC.) TO
C 'VALUE' OVER RANGE IXF TO IXL, IYF TO IYL, IZF TO IZL.
C *CONPOR M U S T N O T BE USED IN CONJUNCTION WITH EXPLICIT
C SETTINGS OF THE ARRAYS (INCLUDING SETTINGS VIA CR).
C-----
C--- GROUP 8. DEPENDENT VARIABLES TO BE SOLVED FOR OR STORED :
C SOLVAR(1-25)<25*.F.>,STOVAR(1-25)<25*.F.>,CONC1(1-4)<4*.T.>
C USE FOLLOWING NAMED INTEGERS FOR ARRAY ELEMENTS 1-20:
C P1,PP,U1,U2,V1,V2,W1,W2,M1,M2,RS,KE,EP,H1,H2,H3,C1,C2,C3,C4.
SOLVAR(P1)=.TRUE.
SOLVAR(PP)=.TRUE.
SOLVAR(V1)=.TRUE.
SOLVAR(W1)=.TRUE.
SOLVAR(H1)=.TRUE.
SOLVAR(KE)=.TRUE.
SOLVAR(EP)=.TRUE.
STOVAR(V2)=.TRUE.
STOVAR(W2)=.TRUE.
STOVAR(C1)=.TRUE.
STOVAR(C2)=.TRUE.
STOVAR(C3)=.TRUE.
C-----
C--- GROUP 9. VARIABLE LABELS :
C TITLE(1-25)<2HP1,2HPP,2HU1,2HU2,2HV1,2HV2,2HW1,2HW2,2HR1,
C 2HR2,2HRS,2HKE,2HEP,2HH1,2HH2,2HH3,2HC1,2HC2,
C 2HC3,2HC4,2HRX,2HRY,2HRZ, 2*4H*****>
TITLE(C1)=TITC1
TITLE(C2)=TITC2
TITLE(C3)=TITC3
TITLE(PP)=TITPP
C-----
C--- GROUP 10 PROPERTIES:
C IRH01<1>,IRH02<1>,RH01<1.0>,RH02<1.0>,
C ARH01<1.0>,BRH01<1.0>,CRH01<1.0>

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C     IEMU1<1>,EMU1<1.0>,EMULAM<1.E-10>          VAN03610
C     IHSAT,H1SAT,H2SAT,PSATEX<1.0>          VAN03620
C     SIGMA(1-25)<1.0,2.0,1.,1.E10,1.,1.E10,1.,1.E10,  VAN03630
C     4*1.0,1.314,1.0,1.E10,10*1.0>          VAN03640
C     IRH01=-1          VAN03650
C     PTOT=55.E5          VAN03660
C     TOT=555.55          VAN03670
C     RAIR=287.          VAN03680
C     GAMA=1.35          VAN03690
C     CP=RAIR/(1-1/GAMA)          VAN03700
C     TW=323.          VAN03710
C     HWALL=TW*CP          VAN03720
C     HTOT=CP*TOT          VAN03730
C     RHTOT=PTOT/TOT/RAIR          VAN03740
C     LOGIC(87)=.TRUE.          VAN03750
C     ARH01=RHTOT/PTOT***(1/GAMA)          VAN03760
C     BRH01=1./GAMA          VAN03770
C   TURBULENT OR LAMINAR          VAN03780
C     IEMU1=2          VAN03790
C   IEMU1=-1          VAN03800
C     JEMU1=IEMU1          VAN03810
C     EMU1=1.E-5          VAN03820
C     EMULAM=EMU1          VAN03830
C     GEMU1=EMU1          VAN03840
C     GPR=.7          VAN03850
C     SIGMA(24)=GPR          VAN03860
C     SIGMA(14)=.9          VAN03870
C-----
C--- GROUP 11 INTER-PHASE TRANSFER PROCESSES :          VAN03880
C     ICFIP,CFIPS,IMDOT,CMDOT,CA1I<1.E6>,CA2I<1.E6>          VAN03890
C-----
C--- GROUP 12 SPECIAL SOURCES :          VAN03900
C     ISPCSO(1-25),AGRAX,AGRACY,AGRAVZ,ABUOY,HREF          VAN03910
C-----
C--- GROUP 13 INITIAL FIELDS :          VAN03920
C     FIINIT(1-25)<25*1.E-10>          VAN03930
C   MACH NO. OF FREE STREAM          VAN03940
C     GMACH=3.2          VAN03950
C     A=1+(GAMA-1)/2*GMACH**2          VAN03960
C     TE=TOT/A          VAN03970
C     RHE=RHTOT/A***(1/(GAMA-1))          VAN03980
C     PSTAT=PTOT/A***(GAMA/(GAMA-1))          VAN03990
C     RH01=ARH01*PSTAT**BRH01          VAN04000
C     SONIC=SQRT(GAMA*RAIR*TE)          VAN04010
C     WIN=SONIC*GMACH          VAN04020
C     RKEIN=0.01*WIN**2          VAN04030
C     EPIN=0.16*RKEIN**1.5/GTH/2.          VAN04040
C     FIINIT(W1)=WIN          VAN04050
C     FIINIT(P1)=PSTAT          VAN04060
C     FIINIT(H1)=HTOT          VAN04070
C     FIINIT(KE)=RKEIN          VAN04080
C     FIINIT(EP)=EPIN          VAN04090
C-----
C--- GROUP 14 BOUNDARY/INTERNAL CONDITIONS :          VAN04100
C     ILOOP1,ILOOPN,XCYCLE<.F.>,PBAR,REGION(1-10)<10*x.T.>          VAN04110
C   *N.B. ALL 10 REGIONS ARE DEFAULTED .TRUE.. THE USER SHOULD          VAN04120
C   SET REGION(I)=.FALSE. FOR UNUSED REGIONS 'I'.          VAN04130
C   DO 14 I=1,10          VAN04140
C   14 REGION(I)=.FALSE.          VAN04150
C-----
C--- GROUP 15 TO 24; REGIONS 1 TO 10          VAN04160
C--- ONLY THOSE REGIONS ARE ACTIVE WHICH ARE SPECIFIED BY THE          VAN04170
C   USER, PREFERABLY BY WAY OF:-          VAN04180
C     CALL PLACE(IREGN,TYPE,IXF,IXL,IYF,IYL,IZF,IZL) &          VAN04190
C     CALL COVAL(IREGN,VARBLE,COEFF,VALUE)          VAN04200
C     CALL PLACE(1,LOW,1,NX,1,NY,1,1)          VAN04210
C     CALL COVAL(1,M1,FIXFLU,WIN*RHE)          VAN04220
C     CDAR CALL COVAL(1,M1,1.E-20,1.E+20*WIN*RHE)          VAN04230
C     GCM=2*GAMA/WIN/(GAMA-1)          VAN04240
C     GVM=PTOT*RHE/RHTOT          VAN04250
C     CALL COVAL(1,M1,GCM,GVM)          VAN04260
C     CALL COVAL(1,W1,ONLYMS,WIN)          VAN04270
C

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        CALL COVAL(1,H1,ONLYMS,HTOT)                      VAN04330
        CALL COVAL(1,KE,ONLYMS,RKEIN)                     VAN04340
        CALL COVAL(1,EP,ONLYMS,EPIN)                      VAN04350
        CALL PLACE(2,HIGH,1,NX,1,NY,NZ,NZ)                VAN04360
C       CALL COVAL(2,M1,FIXVAL,PSTAT*0.)                VAN04370
        CALL COVAL(2,M1,1000*WIN*RHE/PSTAT,PSTAT)         VAN04380
        CALL COVAL(2,H1,ONLYMS,HTOT)                      VAN04390
C       WALL ALONG THE VANE IZ(11,NZ)                  VAN04400
        GCM=EMU1/(.5*BYFRAC(1)*GTH)                     VAN04410
        DY1=BYFRAC(1)*GTH                                VAN04420
        GOEFF=EMU1/(0.5*DY1)                            VAN04430
        GOEFH=EMU1/(0.5*DY1*SIGMA(24))                 VAN04440
        CALL PLACE(3,SOUTH,1,NX,1,1,12,NZ)               VAN04450
C       CALL COVAL(3,W1,GOEFF,0.)                      VAN04460
C       CALL COVAL(3,H1,GOEFH,HWALL)                  VAN04470
        CALL COVAL(3,W1,WALL,0.)                        VAN04480
        CALL COVAL(3,H1,WALL,HWALL)                    VAN04490
        CALL COVAL(3,KE,WALL,0.)                        VAN04500
        CALL COVAL(3,EP,WALL,0.)                        VAN04510
C----- -----
C--- GROUP 25 GROUND STATION :                      VAN04520
C   GROSTA<.F.>,NAMLST<.F.>                   VAN04530
C   *NAMLST ACTIVATES NAMELIST IN GROUND.          VAN04540
C   GROSTA=.TRUE.                                  VAN04550
C----- -----
C--- GROUP 26 SOLUTION TYPE AND RELATED PARAMETERS : VAN04560
C   WHOLEP<.F.>,SUBPST<.F.>,DONACC<.F.>      VAN04570
C   WHOLEP=.TRUE.
C----- -----
C--- GROUP 27 SWEEP AND ITERATION NUMBERS :          VAN04580
C   FSWEET<1>,LSWEET<1>,LITHYD<1>,LITC<1>,LITKE<1>,    VAN04590
C   LITER(1-25)<9x1,-1,15x1>                      VAN04600
C   IVELF<1>,NVEL<1>,IVELL<10000>,              VAN04610
C   IKEF<1>,NKE<1>,IKEL<10000>,                VAN04620
C   IENTF<1>,NENT<1>,IENTL<10000>,              VAN04630
C   ICNCF<1>,NCNC<1>,ICNCL<10000>,            VAN04640
C   IRHO1F<1>,NRHO1<1>,IRHO1L<10000>,          VAN04650
C   IRHO2F<1>,NRHO2<1>,IRHO2L<10000>           VAN04660
C   LSWEET=1201                                     VAN04670
C   GSWP=LSWEET                                    VAN04680
C   FSWEET=801                                      VAN04690
C   LITER(PP)=20                                     VAN04700
C   LITER(V1)=5                                     VAN04710
C   LITER(W1)=5                                     VAN04720
C   LITHYD=2                                       VAN04730
C----- -----
C--- GROUP 28 TERMINATION CRITERIA :                VAN04740
C   ENDIT(1-25)<9x1.E-10,0.5,15x1.E-10>          VAN04750
C   ENDIT(1)=1.E-5                                 VAN04760
C----- -----
C--- GROUP 29 RELAXATION :                          VAN04770
C   RLXP<1.>,RLXPXY<1.>,RLXPZ<1.>,RLXRHO<1.>,RLXMDT<1.>,    VAN04780
C   DTFALS(3-25)<23x1.E10>                      VAN04790
C   DTFALS(W1)=1.E-5                             VAN04800
C   DTFALS(V1)=1.E-5                             VAN04810
C   DTFALS(KE)=1.E-5                             VAN04820
C   DTFALS(EP)=1.E-6                             VAN04830
C   RLXP=.3                                       VAN04840
C----- -----
C--- GROUP 30 LIMITS :                            VAN04850
C   VELMAX<1.E10>,VELMIN<-1.E10>,RHOMAX<1.E10>,RHOMIN<1.E-10>,    VAN04860
C   TKEMAX<1.E10>,TKEMIN<1.E-10>,EMUMAX<1.E10>,EMUMIN<1.E-10>,    VAN04870
C   EPSMAX<1.E10>,EPSMIN<1.E-10>,AMDTMX<1.E10>,AMDTMN<-1.E10>    VAN04880
C   EPSMAX=1.E13                                 VAN04890
C----- -----
C--- GROUP 31 SLOWING DEVICES : SLORHO<1.>,SLOEMU<1.>    VAN04900
C   SLORHO=.2                                     VAN04910
C----- -----
C--- GROUP 32 PRINT-OUT OF VARIABLES :             VAN04920
C   PRINT(1-25)<.T.,.F.,23x.T.>,SUBWGR<.F.>    VAN04930
C   PRINT(C1)=.TRUE.                            VAN04940
C   PRINT(C2)=.TRUE.                            VAN04950
C----- -----
C   VAN04960
C----- -----
C--- GROUP 33 THERMAL COUPLING :                   VAN04970
C   THERMCOUPLING=.TRUE.                         VAN04980
C----- -----
C--- GROUP 34 THERMAL COUPLED ZONE :              VAN04990
C   THERMCOUPLED=.TRUE.                         VAN05000
C----- -----
C--- GROUP 35 THERMAL COUPLED ZONE :              VAN05010
C   THERMCOUPLED=.TRUE.                         VAN05020
C----- -----
C--- GROUP 36 THERMAL COUPLED ZONE :              VAN05030
C   THERMCOUPLED=.TRUE.                         VAN05040

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PRINT(C3)=.TRUE.
PRINT(PP)=.TRUE.
C----- -----
C--- GROUP 33 MONITOR PRINT-OUT :
C   IXMON<1>,IYMON<1>,IZMON<1>,NPRMON<1>,NPRMNT<1>
C   NPRMON=10
C   IYMON=2
C   IZMON=12
C----- -----
C--- GROUP 34 FIELD PRINT-OUT CONTROL :
C   NPRINT<100>,NTPRIN<100>,NXPRIN<1>,NYPRIN<1>,NZPRIN<1>,
C   IZPRF<1>,ISTPRF<1>,IZPRL<10000>,ISTPRL<10000> .
C   NUMCLS<10>,KOUTPT
C   NPRINT=LSWEEP
C----- -----
C--- GROUP 35 TABLE CONTROL :
C   TABLES<.F.>,NTABLE,NTABVR,LINTAB,NPRTAB,NMON,
C   ITAB(1-8),MTABVRC(1-8)
C----- -----
C   GROUP 36-38 ARE NOT DOCUMENTED IN THE INSTRUCTION
C   MANUAL AND ARE INTENDED FOR MAINTENANCE PURPOSES ONLY
C--- GROUP 36 DEBUG PRINT-OUT SLAB AND TIME-STEP :
C   IZPR1<1>,IZPR2<1>,ISTPR1<1>,ISTPR2<1>
C----- -----
C--- GROUP 37 DEBUG SWEEP AND SUBROUTINES :
C   KEMU,KMAIN,KINDEX,KGEOM,KINPUT,KSODAT,KCOMP,F,KSOURCE,
C   KSOLV1,KSOLV2,KSOLV3,KCOMPP,KADJST,KFLUX,KSHIFT,KDIF,
C   KCOMP,U,KCOMP,V,KCOMP,W,KCOMP,R,KWALL,KDBRH0<-1>,KDBEXP,KDBMDT
C   KDBGEN
C----- -----
C--- GROUP 38 MONITOR,TEST, AND FLAG :
C   MONITR<.F.>,FLAG<.F.>,TEST<.T.>,KFLAG<1>
C   END OF MAINTENANCE-ONLY SECTION
C----- -----
C--- GROUP 39 ERROR AND RESIDUAL PRINT-OUT :
C   IERRP<1000>,RESREF(1,3-24)<25*1.>,RESMAP<.F.>,
C   RESID(1-25)<2*F.,23*T.>,KOUTPT
C   RESREF(1)=WIN*RHE
C   RESREF(7)=WIN*RESREF(1)
C   RESREF(5)=WIN*RESREF(1)*0.1
C   RESREF(H1)=HTOT*RESREF(1)
C   RESREF(KE)=RKEIN*RESREF(1)
C   RESREF(EP)=EPIN*RESREF(1)
C   IERRP=LSWEEP/20
C   KOUTPT=LSWEEP/20
C----- -----
C--- GROUP 40 SPECIAL DATA : LOGIC(1..10),INTGR(1..10),RE(21..30),
C   NLSP<1>,NISP<1>,NRSP<1>,SPDATA<.F.>,LSPDA(1),ISPDA(1),RSPDA(1)
C   USE FIRST 10 ELEMENTS OF ARRAYS LOGIC & INTGR AND 21ST
C   TO 30TH OF ARRAY RE FOR TRANSFERRING SPECIAL DATA FROM
C   SATELLITE TO GROUND, BUT IF REQUIREMENTS EXCEED THIS
C   PROVISION SET SPDATA = .T., AND DIMENSION ARRAYS LSPDA,
C   ISPDA, RSPDA ABOVE AND IN GROUND AS NEEDED, AND SET HERE
C----- -----
C--- GROUP 42 RESTARTS AND DUMPS : SAVEM<.F.>,RESTRT<.F.>,KINPUT
C   SAVEM=.TRUE.
C   BFPLOT=.TRUE.
C   RESTRT=.TRUE.
C----- -----
C--- GROUP 43 GRAFFIC :
C   GRAPHS<.F.>,ORTHOG<.T.>,ANTSYM,NPRT<1>,ITITL<5*4H****>
C--- FOR A GRAFFIC RUN, DIMENSION PHI1 & PHI2 AS FOLLOWS:
C   PHI1(NX*NY*NZ*NM)
C   PHI2((NX+2)*(NY+2)*(NZ+2)*(NM+IBLK)) , WHERE
C   NM=NO. OF VARIABLES STORED + DENSITY(-IES)
C   IBLK=0 IF BLOCK=.FALSE.,=4 IF A 3D RUN,
C   =3 IF A 2D.YZ RUN.
C----- -----
      IF(IRUN.EQ.1) GO TO 900
900 CONTINUE
C--- ALL RUNS

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XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 3 ENDS.          VAN05770
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 4 STARTS:  VAN05780
C-----                                         VAN05790
C-----                                         VAN05800
C----- WRITE GENERAL DATA ON TO THE GUSIE1.DTA TAPE, ETC...    VAN05810
  IF(SPDATA) CALL WRTSPC(LSPDA,NLSP,ISPDA,NISP,RSPDA,NRSP)  VAN05820
    IF(BLOCK) CALL WRTPOR(PE,PN,PH,PC,NX,NY,NZ,IPLANE)      VAN05830
      IF(BFC) CALL WRTBFC(14,NBFC,XE,XW,YN,YS,ZH,ZL,          VAN05840
      &ND,NX+1,NY+1,NZ+1,NZ,PRTBFC)
C----- OLD PRACTICES RETAINED FOR REFERENCE:                VAN05850
  IF(SPDATA) CALL SPCDAT(IRUN)                                VAN05860
  IF(BLOCK) CALL PORDAT(IRUN)                                VAN05870
  IF(GRAPHS) CALL SORT(IRUN)                                 VAN05880
  IF(RESTRT) GO TO 902                                     VAN05890
  DO 901 INDFVAR=1,25                                     VAN05900
    IF(IFIX(FIINIT(INDVAR)+0.1).NE.10101) GO TO 901        VAN05910
  CALL FLDDAT(IRUN)                                         VAN05920
  GO TO 902                                              VAN05930
901 CONTINUE                                             VAN05940
902 CALL DATAIO(WRT,10)                                    VAN05950
  IF(MONITR) CALL DATAIO(WRT,-6)                          VAN05960
999 CONTINUE                                              VAN05970
STOP
END
C*** IGEN=1 SO BFCXYZ NOT REQUIRED.                      VAN06000
C*** COMMENT OUT BOTH VERSIONS.                         VAN06010
C-----                                         VAN06020
C----- SUBROUTINE BFCXYZ (NXP1,NYP1,NZP1)               VAN06030
RETURN
END
VAN06040
VAN06050

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C-----          VAN00730
C CHAPTER 2 SET CONSTANTS, AND ARRANGE FILE MANIPULATIONS.          VAN00740
C-----          VAN00750
C PLEASE DO NOT ALTER, OR RE-SET, ANY OF THE REMAINING          VAN00760
C STATEMENTS OF THIS CHAPTER.          VAN00770
C DATA CELL,EAST,WEST,NORTH,SOUTH,HIGH,LOW,VOLUME/          VAN00780
C & 0.,1.,2.,3.,4.,5.,6.,7. /          VAN00790
C DATA P1,PP,U1,U2,V1,V2,W1,W2,R1,R2,RS,KE,EP,H1,H2,H3,C1,C2,          VAN00800
C &C3,C4/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20/          VAN00810
C DATA FIXFLU,FIXVAL,ONLYMS,WALL/1.E-10,1.E10,0.0,-10.0/          VAN00820
C DATA IPLANE,XPLANE,YPLANE,ZPLANE/0,1,2,3/          VAN00830
C DATA WRT,RD,DFFAULT/.TRUE.,.FALSE.,4HDEFA,4HULT.,4HDTA/,1HG/          VAN00840
C DATA GDTAPE/4HGUSI,4HE1.D,2HTA/          VAN00850
C DATA NLDATA,NIDATA,NRDATA/309,194,421/          VAN00860
C DATA NLCREG,NTCVRG/60,350/          VAN00870
C DATA TITPP,TITCI,TITC2,TITC3/3HRHO,4HMACH,4HTEMP,4HCFST/          VAN00880
C CALL TAPES(10,GDTAPE,3,1,4*NRDATA)          VAN00890
C-----          VAN00900
C READ DEFAULT FILE IF BLOCKDATA ABSENT          VAN00910
C     IF(INTGR1(29).NE.10) GO TO 2          VAN00920
C     CALL WRIT40(40HDATA ESTABLISHED IN BLOCK DATA. )          VAN00930
C     GO TO 3          VAN00940
C 2 CALL DEFLT          VAN00950
CD 2 CALL TAPES(1,DFFAULT,4,2,4*NRDATA)          VAN00960
CD CALL DATAIO(RD,1)          VAN00970
C     CALL WRIT40(40HDATA TAKEN FROM DEFAULT.DTA ON GROUP A/C)          VAN00980
C 3 CALL WRIT40(40HFILE MODSTL.FTN IS THE SATLIT USED. )          VAN00990
C-----          VAN01000
C CHAPTER 3 DEFINE DATA FOR NRUN RUNS.          VAN01010
C-----          VAN01020
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 2 ENDS.          VAN01030
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 2 STARTS:          VAN01040
C--- GROUP 41MULTI-RUNS : RUN(1-30)<.T.,29*.F.>          VAN01050
C-----          VAN01060
C     RUN(1)=.FALSE.          VAN01070
C NOTE: ALL RUNS ARE DEACTIVATED AT THIS POINT - USER SHOULD          VAN01080
C ===== SWITCH ON ONE ONLY OF RUNS 1-4 IN NEXT STATEMENT.          VAN01090
C     RUN(1)=.TRUE.          VAN01100
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 2 ENDS.          VAN01110
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 3 STARTS:          VAN01120
C     DO 10 IRUN=1,30          VAN01130
C       IF(.NOT.RUN(IRUN)) GO TO 10          VAN01140
C       NRUN=NRUN+1          VAN01150
C       LSTRUN=IRUN          VAN01160
C 10 CONTINUE          VAN01170
C     DO 999 IRUN=1,LSTRUN          VAN01180
C       IF(.NOT.RUN(IRUN)) GO TO 999          VAN01190
C       INTGR(11) = IRUN          VAN01200
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 3 ENDS.          VAN01210
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 3 STARTS:          VAN01220
C--- ALL INTEGER VARIABLES ARE DEFAULTED TO 0, AND REAL VARIABLES          VAN01230
C TO 0.0, UNLESS OTHERWISE INDICATED.          VAN01240
C E.G. BY VARIABLE<10>, OR <10.0> AS APPROPRIATE.          VAN01250
C THE DEFAULT SETTINGS OF ALL LOGICAL VARIABLES ARE ALWAYS          VAN01260
C INDICATED, E.G. VARIABLE<.T.>, OR VARIABLE<.F.>.          VAN01270
C-----          VAN01280
C--- RUN1          VAN01290
C-----          VAN01300
C--- GROUP 1. FLOW TYPE :          VAN01310
C   PARAB<.F.>,CARTES<.T.>,ONEPHS<.T.>          VAN01320
C-----          VAN01330
C--- GROUP 2. TRANSIENCE :          VAN01340
C   STEADY<.T.>,ATIME,LSTEP<1>,FSTEP<1>          VAN01350
C   TLAST<1.E10>,TFRAC(1-30)<30*1.>          VAN01360
C SERVICE SUBROUTINE FOR 'NT' POWER-LAW TIME STEPS:          VAN01370
C   CALL GRDPWR(0,NT,TLAST,POWER)          VAN01380
C-----          VAN01390
C--- GROUP 3. X-DIRECTION :          VAN01400
C   NX<1>,XULAST<1.0>,XFRAC(1-30)          VAN01410
C SERVICE SUBROUTINE FOR POWER-LAW GRID:          VAN01420
C   CALL GRDPWR(1,NX,XULAST,POWER)          VAN01430
C-----          VAN01440

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C--- GROUP 4. Y-DIRECTION :                               VAN01450
C   NY<1>,YVLAST<1.0>,YFRAC(1-30),RINNER,SNALFA    VAN01460
C   SERVICE SUBROUTINE FOR POWER-LAW GRID:             VAN01470
C   CALL GRDPWR(2,NY,YVLAST,POWER)                      VAN01480
C   NY=18                                              VAN01490
C-----                                              VAN01500
C--- GROUP 5. Z-DIRECTION :                               VAN01510
C   NZ<1>,ZWLAST<1.0>,ZFRAC(1-30)                   VAN01520
C   SERVICE SUBROUTINE FOR POWER-LAW GRID:             VAN01530
C   CALL GRDPWR(3,NZ,ZWLAST,POWER)                      VAN01540
C   NZ=29                                              VAN01550
C-----                                              VAN01560
C--- GROUP 6. MOVING GRID OR DISTORTED (BODY-FITTED) GRID : VAN01570
C   --- MOVING GRID :                                 VAN01580
C   MGRID,IZW1,IZW2,AZW2,BZW2,CZW2,PINT,ZW2M1T        VAN01590
C-----                                              VAN01600
C   --- BODY-FITTED GRID ---                           VAN01610
C   BFC<.T.>,IGEN<1>,ND<1>,NBFC<5000>,KOORD,RCON    VAN01620
C   BXFRAC(1-NX)<1.0,NXM1*0.0>                      VAN01630
C   BYFRAC(1-NY)<1.0,NYM1*0.0>                      VAN01640
C   BZFRAC(1-NZ)<1.0,NZM1*0.0>                      VAN01650
C   SERVICE SUBROUTINE FOR SUB-DOMAIN SPECIFICATION (FOR IGEN=1 VAN01660
C ONLY):                                             VAN01670
C     CALL DOMAIN(ID,IXF,IXL,IYF,IYL,IZF,IZL)          VAN01680
C   XE(1-NYP1,1-NZP1,1-ND)<(NYP1*NZP1*ND)*1.0>,       VAN01690
C   XW(1-NYP1,1-NZP1,1-ND),                            VAN01700
C   YN(1-NXP1,1-NZP1,1-ND)<(NXP1*NZP1*ND)*1.0>,       VAN01710
C   YS(1-NXP1,1-NZP1,1-ND),                            VAN01720
C   ZH(1-NXP1,1-NYP1,1-ND)<(NXP1*NYP1*ND)*1.0>,       VAN01730
C   ZL(1-NXP1,1-NYP1,1-ND),STORSA(1-6)<6x.F.>,STORWD(1-6)<6x.F.>, VAN01740
C   STORP<.F.>,STORPE<.F.>,STORPN<.F.>,STORPH<.F.>,STOUNV<.F.>, VAN01750
C   PRTBFC<.F.>,DARCY,BFPLOT<.F.>                  VAN01760
C CYCLIC BOUNDARY CONDITIONS ARE DEFAULTED INACTIVE ; VAN01770
C TO ACTIVATE THEM AT SELECTED IZ SLABS USE SERVICE SUBROUTINE: VAN01780
C   CALL XCYIZ(IZ,.TRUE.)                                VAN01790
C SERVICE SUBROUTINE TO DEACTIVATE CURVATURE TERMS IN U, V VAN01800
C AND W EQUATIONS ASSOCIATED WITH CURVATURE OF IX, IY, IZ VAN01810
C GRID LINES RESPECTIVELY:                                VAN01820
C   CALL UCURVE(IZ,.FALSE.)                             VAN01830
C   CALL VCURVE(IZ,.FALSE.)                            VAN01840
C   CALL WCURVE(IZ,.FALSE.)                            VAN01850
C NCART<1>                                              VAN01860
C *WARNINGS!!!!!!                                         VAN01870
C-----                                              VAN01880
C   A) WHEN USING BFC'S STOVAR(H3), STOVAR(C4), STOVAR(21) ARE VAN01890
C      AVAILABLE ONLY FOR STORING NON-ORTHOGONAL VELOCITY VAN01900
C      COMPONENTS.                                         VAN01910
C   B) MULTI-RUNS ARE NOT ALLOWED WITH BFC OPTION.        VAN01920
C   C) MOVING GRID, TWO-PHASE AND PARABOLIC OPTIONS ARE NOT VAN01930
C      AVAILABLE WITH BFC OPTION.                         VAN01940
C   D) KE-EP TURBULENCE MODEL SHOULD BE USED WITH BFC'S ONLY VAN01950
C      WHEN THE MAIN FLOW IS IN THE IZ DIRECTION.        VAN01960
C   E) BUILT-IN GRAVITY TERMS DO NOT TAKE ACCOUNT OF BFC'S. VAN01970
C *NOTES                                              VAN01980
C-----                                              VAN01990
C   A) THE STANDARD VELOCITY-FIELD PRINTOUT FOR THE VAN02000
C      VELOCITY RESOLUTES IS ACTIVATED IN THE USUAL VAN02010
C      WAY. AN ADDITIONAL OPTION EXISTS FOR PRINTING THE VAN02020
C      CARTESIAN VELOCITY-COMPONENTS WHICH MAY BE VAN02030
C      ACTIVATED BY SETTING THE FOLLOWING LOGICALS:       VAN02040
C        STOVAR(U2)=.T. FOR U-COMPONENT (CARTESIAN)        VAN02050
C        STOVAR(V2)=.T. FOR V-COMPONENT (CARTESIAN)        VAN02060
C        STOVAR(W2)=.T. FOR W-COMPONENT (CARTESIAN)        VAN02070
C      SIMILARLY PRINTOUT OF NON-ORTHOGONAL VELOCITY VAN02080
C      COMPONENTS MAY BE ACTIVATED AS FOLLOWS:           VAN02090
C        STOVAR(C4)=.T. FOR U-COMPONENT (NON-ORTHOG)       VAN02100
C        STOVAR(H3)=.T. FOR V-COMPONENT (NON-ORTHOG)       VAN02110
C        STOVAR(21)=.T. FOR W-COMPONENT (NON-ORTHOG)       VAN02120
C   B) BFC (TO ACTIVATE THE BFC OPTION), IGEN (THE CODE FOR METHOD VAN02130
C      OF GRID SPECIFICATION), ND (NUMBER OF SUB-DOMAINS) AND VAN02140
C      NBFC (THE F1 ARRAY DIMENSION), MUST BE SET BEFORE VAN02150
C      "STANDARD BFC SECTION 2".                         ====== VAN02160

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C           ALL OTHER BFC DATA MUST BE SET AFTER "STANDARD BFC
C           SECTION 2.          =====
C           C) NXPI, NYPI, NZPI STORE NX+1, NY+1, NZ+1; THESE ARE
C           AVAILABLE TO USER AFTER STANDARD BFC SECTION 2.
C           D) FOR IGEN=1 USE BXFRAC,BYFRAC & BZFRAC IN PLACE OF
C           XFRAC,YFRAC & ZFRAC.
C-----  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 1 STARTS:  

C   DEFAULT SETTINGS:  

NCART=10  

BFC=.TRUE.  

IGEN=1  

ND=1  

NBFC=5000  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 1 ENDS.:  

C   *USER SETS BFC, IGEN, ND AND NBFC HERE:  

C-----  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 2 STARTS:  

CALL SB4I(NXPI,NX+1,NYPI,NY+1,NZPI,NZ+1,I,0)  

IF(BFC) CALL BFCDFT(NBFC,XE,XW,YN,YS,ZH,ZL,ND,NXPI,NYPI,  

&                           NZPI,NZ)  

CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD BFC SECTION 2 ENDS.  

C   *USER SETS ALL OTHER BFC VARIABLES HERE:  

C   *USING NONIFORM GRID 1-8  

GTH=65.E-3  

GTL=150.E-3  

GBETA=4.  

GBETA=GBETA*3.1415927/180  

GTAB=TAN(GBETA)  

DELMAX=2.E-3  

GNBL=5.  

GPWR=4.  

DO 64 IY=1,5  

64 BYFRAC(IY)=(FLOAT(IY)/GNBL)*GPWR*DELMAX/GTH  

BYFRAC(6)=BYFRAC(5)+3.E-3/GTH  

DEL=(1.-BYFRAC(6))/(FLOAT(NY)-GNBL-1)  

DO 65 IY=7,NY  

65 BYFRAC(IY)=BYFRAC(IY-1)+DEL  

C-----ZZ-----  

BZFRAC(1)=10.E-3  

DO 66 IZ=2,5  

66 BZFRAC(IZ)=10.E-3+BZFRAC(IZ-1)  

BZFRAC(6)=BZFRAC(5)+5.E-3  

DO 67 IZ=7,9  

67 BZFRAC(IZ)=BZFRAC(IZ-1)+2.E-3  

DO 68 IZ=10,11  

68 BZFRAC(IZ)=BZFRAC(IZ-1)+.5E-3  

BZFRAC(12)=BZFRAC(11)+1.E-3  

DO 77 IZ=13,14  

77 BZFRAC(IZ)=BZFRAC(IZ-1)+.5E-3  

DO 78 IZ=15,15  

78 BZFRAC(IZ)=BZFRAC(IZ-1)+1.E-3  

BZFRAC(16)=BZFRAC(15)+1.E-3  

BZFRAC(17)=BZFRAC(16)+2.E-3  

BZFRAC(18)=BZFRAC(17)+7.E-3  

DO 69 IZ=19,22  

69 BZFRAC(IZ)=BZFRAC(IZ-1)+10.E-3  

BZFRAC(23)=BZFRAC(22)+3.E-3  

BZFRAC(24)=BZFRAC(23)+2.E-3  

BZFRAC(25)=BZFRAC(24)+2.E-3  

BZFRAC(26)=BZFRAC(25)+3.E-3  

BZFRAC(27)=BZFRAC(26)+5.E-3  

DO 71 IZ=28,NZ  

71 BZFRAC(IZ)=BZFRAC(IZ-1)+10.E-3  

DO 72 IZ=1,NZ  

72 BZFRAC(IZ)=BZFRAC(IZ)/GTL  

CALL DOMAIN(1,1,NX,1,NY,1,NZ)  

DO 61 IX=1,NXPI  

DO 62 IY=1,NYPI  

ZL(IX,IY,1)=0.0  

62 ZH(IX,IY,1)=GTL  

DO 63 IZ=1,NZPI

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      YN(IX,IZ,1)=GTH          VAN02890
  63  YS(IX,IZ,1)=0.0        VAN02900
C   YS(IX,13,1) SHOULD COME AFTER VAN02910
    DO 662 IZ=5,25           VAN02920
CBL  DO 662 IZ=16,25         VAN02930
  662  YS(IX,IZ,1)=(BZFRAC(IZ-1)-BZFRAC(3))*GTAB*GTL VAN02940
CBL  DO 663 IZ=13,15         VAN02950
CBL  GZ12=(BZFRAC(IZ-1)-BZFRAC(11))*GTL-.5E-3       VAN02960
CBL663YS(IX,IZ,1)=SQRT(YS(IX,16,1)*GZ12*2.-GZ12**2) VAN02970
    DO 664 IZ=26,NZ          VAN02980
  664  YS(IX,IZ,1)=YS(IX,25,1) VAN02990
  61  CONTINUE               VAN03000
    STORSA(IFIX(LOW))=.TRUE. VAN03010
    STORSA(IFIX(HIGH))=.TRUE. VAN03020
    STORSA(IFIX(SOUTH))=.TRUE. VAN03030
    STORWD(IFIX(SOUTH))=.TRUE. VAN03040
    STORP=.TRUE.              VAN03050
    PRTBFC=.TRUE.             VAN03060
CDAR  DARCY=1.E10            VAN03070
C-----
C--- GROUP 7. BLOCKAGE: BLOCK<.F.>, IPLANE, IPWRIT          VAN03080
C   *SET CONSTANT POROSITIES OVER SUB-DOMAINS USING:        VAN03090
C     CALL CONPOR(IR,TYPE,VALUE,IXF,IXL,IYF,IYL,IZF,IZL), WHERE: VAN03100
C     IR=RUN SECTION NUMBER, E.G. 1 FOR RUN1 SECTION; 'TYPE'= EAST, VAN03110
C     WEST, NORTH, SOUTH, HIGH, LOW & CELL. 'VALUE'=WANTED POROSITY VAN03120
C     OVER REGION IXF,...IZL.                                VAN03130
C   *DIMENSION ARRAYS PE(NX,NY,NZ), PN(NX,NY,NZ), PH(NX,NY,NZ), & VAN03140
C     PC(NX,NY,NZ) ABOVE.                                     VAN03150
C   *FOR FULLY-BLOCKED CELLS (IE. 'VALUE'= 0.0) USER NEED SET ONLY VAN03160
C     THE 'CELL' POROSITY (TO ZERO), AS CELL-FACE AREAS ARE THEN VAN03170
C     AUTOMATICALLY ZEROED.                                 VAN03180
C   *FOR SATELLITE PRINTOUT OF ALL POROSITIES IN DOMAIN, 'IPLANE'= VAN03190
C     XPLANE YPLANE OR ZPLANE, FOR DESIRED CROSS-SECTION DIRECTION. VAN03200
C   *FOR EACH 'TYPE' A MAXIMUM OF 10 CALLS TO CONPOR IS ALLOWED, VAN03210
C     BUT IF REQUIREMENTS EXCEED THIS PROVISION SET BLOCK=.T. & VAN03220
C     IPWRIT=-1, AND SET POROSITY ARRAYS EXPLICITLY HERE AS WANTED. VAN03230
C     IN THIS CASE, THE USER M U S T SET A L L ELEMENTS OF VAN03240
C     ARRAYS PE, PN, PH, PC (MANY MAY BE 0.0 OR 1.0). HE MAY USE: VAN03250
C     CALL CR(PARRAY,VALUE,IXF,IXL,IYF,IYL,IZF,IZL,NX,NY,NZ) VAN03260
C     ANY NUMBER OF TIMES, TO SET 'PARRAY' (= PE, ETC.) TO VAN03270
C     'VALUE' OVER RANGE IXF TO IXL, IYF TO IYL, IZF TO IZL. VAN03280
C   *CONPOR M U S T N O T BE USED IN CONJUNCTION WITH EXPLICIT VAN03290
C     SETTINGS OF THE ARRAYS (INCLUDING SETTINGS VIA CR). VAN03300
C-----
C--- GROUP 8. DEPENDENT VARIABLES TO BE SOLVED FOR OR STORED : VAN03310
C   SOLVAR(1-25)<25*.F.>,STOVAR(1-25)<25*.F.>,CONC1(1-4)<4*.T.> VAN03320
C   USE FOLLOWING NAMED INTEGERS FOR ARRAY ELEMENTS 1-20!          VAN03330
C   P1,PP,U1,U2,V1,V2,W1,W2,M1,M2,RS,KE,EP,H1,H2,H3,C1,C2,C3,C4. VAN03340
C   SOLVAR(P1)=.TRUE.          VAN03350
C   SOLVAR(PP)=.TRUE.          VAN03360
C   SOLVAR(V1)=.TRUE.          VAN03370
C   SOLVAR(W1)=.TRUE.          VAN03380
C   SOLVAR(H1)=.TRUE.          VAN03390
CT   SOLVAR(KE)=.TRUE.          VAN03400
CT   SOLVAR(EP)=.TRUE.          VAN03410
CT   STOVAR(V2)=.TRUE.          VAN03420
CT   STOVAR(W2)=.TRUE.          VAN03430
CT   STOVAR(C1)=.TRUE.          VAN03440
CT   STOVAR(C2)=.TRUE.          VAN03450
CT   STOVAR(C3)=.TRUE.          VAN03460
C-----
C--- GROUP 9. VARIABLE LABELS :          VAN03470
C   TITLE(1-25)<2HP1,2HPP,2HU1,2HU2,2HV1,2HV2,2HW1,2HW2,2HR1, VAN03480
C   2HR2,2HRS,2HKE,2HEP,2HH1,2HH2,2HH3,2HC1,2HC2,          VAN03490
C   2HC3,2HC4,2HRX,2HRY,2HRZ, 2*4H****>          VAN03500
C   TITLE(C1)=TITC1          VAN03510
C   TITLE(C2)=TITC2          VAN03520
C   TITLE(C3)=TITC3          VAN03530
C   TITLE(PP)=TITPP          VAN03540
C-----
C--- GROUP 10 PROPERTIES:          VAN03550
C   IRH01<1>,IRH02<1>,RH01<1.0>,RH02<1.0>,          VAN03560
C                                         VAN03570
C-----          VAN03580
C-----          VAN03590
C-----          VAN03600

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C      ARH01<1.0>,BRH01<1.0>,CRH01<1.0>          VAN03610
C      IEMU1<1>,EMU1<1.0>,EMULAM<1.E-10>        VAN03620
C      IHSAT,H1SAT,H2SAT,PSATEX<1.0>            VAN03630
C      SIGMA(1-25)<1.0,2.0,1.,1.E10,1.,1.E10,       VAN03640
C      4*1.0,1.314,1.0,1.E10,10*1.0>             VAN03650
C      IRHO1=-1                                     VAN03660
C      PTOT=55.E5                                    VAN03670
C      TOT=555.55                                   VAN03680
C      RAIR=287.                                    VAN03690
C      GAMA=1.35                                    VAN03700
C      CP=RAIR/(1-1/GAMA)                         VAN03710
C      TW=323.                                     VAN03720
C      HWALL=TW*CP                                VAN03730
C      HTOT=CP*TOT                               VAN03740
C      RHTOT=PTOT/TOT/RAIR                         VAN03750
C      LOGIC(87)=.TRUE.                           VAN03760
C      ARH01=RHTOT/PTOT***(1/GAMA)                VAN03770
C      BRH01=1./GAMA                             VAN03780
C  TURBULENT OR LAMINAR                         VAN03790
C      IEMU1=-1                                    VAN03800
C      IEMU1=1                                     VAN03810
C      JEMU1=IEMU1                                VAN03820
C      EMU1=1.E-5                                  VAN03830
C      EMULAM=EMU1                                VAN03840
C      GEMU1=EMU1                                VAN03850
C      GPR=.7                                     VAN03860
C      SIGMA(24)=GPR                            VAN03870
C      SIGMA(14)=GPR                            VAN03880
C----- GROUP 11 INTER-PHASE TRANSFER PROCESSES :    VAN03890
C      ICFIP,CFIPS,IMDOT,CMDOT,CA1I<1.E6>,CA2I<1.E6>  VAN03900
C----- GROUP 12 SPECIAL SOURCES :                  VAN03910
C      ISPCSO(1-25),AGRAVX,AGRACY,AGRAVZ,ABUOY,HREF   VAN03920
C----- GROUP 13 INITIAL FIELDS :                 VAN03930
C      FIINIT(1-25)<25*1.E-10>                   VAN03940
C      MACH NO. OF FREE STREAM                      VAN03950
C      GMACH=3.2                                    VAN03960
C      A=1+(GAMA-1)/2*GMACH**2                    VAN03970
C      TE=TOT/A                                    VAN03980
C      RHE=RHTOT/A***(1/(GAMA-1))                VAN03990
C      PSTAT=PTOT/A***(GAMA/(GAMA-1))           VAN04000
C      RH01=ARH01*PSTAT**BRH01                     VAN04010
C      SONIC=SQRT(GAMA*RAIR*TE)                  VAN04020
C      WIN=SONIC*GMACH                          VAN04030
C      RKEIN=0.01*WIN**2                         VAN04040
C      EPIN=0.16*RKEIN**1.5/GTH/2.                VAN04050
C      FIINIT(W1)=WIN                           VAN04060
C      FIINIT(P1)=PSTAT                         VAN04070
C      FIINIT(H1)=HTOT                         VAN04080
C      FIINIT(KE)=RKEIN                        VAN04090
C      FIINIT(EP)=EPIN                         VAN04100
C----- GROUP 14 BOUNDARY/INTERNAL CONDITIONS :    VAN04110
C      ILOOP1,ILOOPN,XCYCLE<.F.>,PBAR,REGION(1-10)<10*T.T.>  VAN04120
C      *N.B. ALL 10 REGIONS ARE DEFAULTED .TRUE.. THE USER SHOULD  VAN04130
C      SET REGION(I)=.FALSE. FOR UNUSED REGIONS 'I'.    VAN04140
C      DO 14 I=1,10                                VAN04150
C      14 REGION(I)=.FALSE.                      VAN04160
C----- GROUP 15 TO 24; REGIONS 1 TO 10          VAN04170
C----- ONLY THOSE REGIONS ARE ACTIVE WHICH ARE SPECIFIED BY THE  VAN04180
C      USER, PREFERABLY BY WAY OF:-              VAN04190
C      CALL PLACE(IREGN,TYPE,IXF,IXL,IYF,IYL,IZF,IZL) &  VAN04200
C      CALL COVAL(IREGN,VARBLE,COEFF,VALUE)        VAN04210
C      CALL PLACE(1,LOW,1,NX,1,NY,1,1)            VAN04220
C      CALL COVAL(1,M1, FIXFLU,WIN*RHE)          VAN04230
CDAR   CALL COVAL(1,M1,1.E-20,1.E+20*WIN*RHE)    VAN04240
C      GCM=2*GAMA/WIN/(GAMA-1)                  VAN04250
C      GVM=PTOT*RHE/RHTOT                      VAN04260
C      CALL COVAL(1,M1,GCM,GVM)                 VAN04270
C

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        CALL COVAL(1,W1,ONLYMS,WIN)           VAN04330
        CALL COVAL(1,H1,ONLYMS,HTOT)          VAN04340
C     CALL COVAL(1,KE,ONLYMS,RKEIN)         VAN04350
C     CALL COVAL(1,EP,ONLYMS,EPIN)          VAN04360
        CALL PLACE(2,HIGH,1,NX,1,NY,NZ,NZ)   VAN04370
C     CALL COVAL(2,M1,FIXVAL,PSTAT*X0.)    VAN04380
        CALL COVAL(2,M1,1000*WIN*RHE/PSTAT,PSTAT) VAN04390
        CALL COVAL(2,H1,ONLYMS,HTOT)          VAN04400
C     WALL ALONG THE VANE IZ(11,NZ)        VAN04410
        GCM=EMU1/(.5*BYFRAC(1)*GTH)        VAN04420
        DY1=BYFRAC(1)*GTH                   VAN04430
        GOEFF=EMU1/(0.5*DY1)                VAN04440
        GOEFH=EMU1/(0.5*DY1*SIGMA(24))      VAN04450
        CALL PLACE(3,SOUTH,1,NX,1,1,4,NZ)    VAN04460
C     CALL COVAL(3,W1,GOEFF,0.)            VAN04470
C     CALL COVAL(3,H1,GOEFH,HWALL)         VAN04480
        CALL COVAL(3,W1,WALL,0.)             VAN04490
        CALL COVAL(3,H1,WALL,HWALL)          VAN04500
CT    CALL COVAL(3,KE,WALL,0.)             VAN04510
CT    CALL COVAL(3,EP,WALL,0.)             VAN04520
C-----
C--- GROUP 25 GROUND STATION :
C     GROSTA<.F.>,NAMLST<.F.>          VAN04540
C     *NAMLST ACTIVATES NAMELIST IN GROUND. VAN04550
C     GROSTA=.TRUE.                         VAN04560
C----- VAN04570
C----- VAN04580
C--- GROUP 26 SOLUTION TYPE AND RELATED PARAMETERS :
C     WHOLEP<.F.>,SUBPST<.F.>,DONACC<.F.> VAN04590
C     WHOLEP=.TRUE.                         VAN04600
C----- VAN04610
C----- VAN04620
C--- GROUP 27 SWEEP AND ITERATION NUMBERS :
C     FSWEET<1>,LSWEET<1>,LITHYD<1>,LITC<1>,LITKE<1>,LITH<1>, VAN04630
C     LITER(1-25)<9x1,-1,15x1>              VAN04640
C     IVELF<1>,NVEL<1>,IVELL<10000>,       VAN04650
C     IKEF<1>,NKE<1>,IKEL<10000>,          VAN04660
C     IENTF<1>,NENT<1>,IENTL<10000>,        VAN04670
C     ICNCF<1>,NCNC<1>,ICNCL<10000>,        VAN04680
C     IRHO1F<1>,NRHO1<1>,IRHO1L<10000>,      VAN04690
C     IRHO2F<1>,NRHO2<1>,IRHO2L<10000>       VAN04700
C     LSWEET=400                            VAN04710
C     GSWEET=LSWEET                         VAN04720
CR    FSWEET=200                           VAN04730
        LITER(PP)=20                          VAN04740
        LITER(V1)=5                           VAN04750
        LITER(W1)=5                           VAN04760
C     LITHYD=2                            VAN04770
C----- VAN04780
C----- VAN04790
C--- GROUP 28 TERMINATION CRITERIA :
C     ENDIT(1-25)<9x1.E-10,0.5,15x1.E-10>   VAN04800
C     ENDIT(1)=1.E-5                         VAN04810
C----- VAN04820
C----- VAN04830
C--- GROUP 29 RELAXATION :
C     RLXP<1.>,RLXPXY<1.>,RLXPZ<1.>,RLXRHO<1.>,RLXMDT<1.>, VAN04840
C     DTFALS(3-25)<23x1.E10>               VAN04850
C     DTFALS(W1)=1.E-5                      VAN04860
C     DTFALS(V1)=1.E-5                      VAN04870
C     RLXP=.2                             VAN04880
C----- VAN04890
C----- VAN04900
C--- GROUP 30 LIMITS :
C     VELMAX<1.E10>,VELMIN<-1.E10>,RHOMAX<1.E10>,RHOMIN<1.E-10>, VAN04910
C     TKEMAX<1.E10>,TKEMIN<1.E-10>,EMUMAX<1.E10>,EMUMIN<1.E-10>, VAN04920
C     EPSMAX<1.E10>,EPSMIN<1.E-10>,AMDTMX<1.E10>,AMDTMN<-1.E10> VAN04930
C----- VAN04940
C----- VAN04950
C--- GROUP 31 SLOWING DEVICES : SLORHO<1.>,SLOEMU<1.>
C     SLORHO=.2                           VAN04960
C----- VAN04970
C----- VAN04980
C--- GROUP 32 PRINT-OUT OF VARIABLES :
C     PRINT(1-25)<.T.,.F.,23x.T.>,SUBWGR<.F.> VAN04990
        PRINT(C1)=.TRUE.                      VAN05000
        PRINT(C2)=.TRUE.                      VAN05010
        PRINT(C3)=.TRUE.                      VAN05020
        PRINT(PP)=.TRUE.                      VAN05030
        PRINT(PP)=.TRUE.                      VAN05040

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C----- -----
C--- GROUP 33 MONITOR PRINT-OUT :           VAN05050
C   IXMON<1>,IYMON<1>,IZMON<1>,NPRMON<1>,NPRMNT<1>    VAN05060
C   NPRMON=5                                     VAN05070
C   IYMON=2                                      VAN05080
C   IZMON=12                                     VAN05090
C----- -----
C--- GROUP 34 FIELD PRINT-OUT CONTROL :      VAN05100
C   NPRINT<100>,NTPRIN<100>,NXPRIN<1>,NYPRIN<1>,NZPRIN<1>,    VAN05110
C   IZPRF<1>,ISTPRF<1>,IZPRL<10000>,ISTPRL<10000>    VAN05120
C   NUMCLS<10>,KOUTPT                         VAN05130
C   NPRINT=LSWEEP                                VAN05140
C----- -----
C--- GROUP 35 TABLE CONTROL :                 VAN05150
C   TABLES<.F.>,NTABLE,NTABVR,LINTAB,NPRTAB,NMON,    VAN05160
C   ITAB(1-8),MTABVR(1-8)                      VAN05170
C----- -----
C   GROUP 36-38 ARE NOT DOCUMENTED IN THE INSTRUCTION    VAN05180
C   MANUAL AND ARE INTENDED FOR MAINTENANCE PURPOSES ONLY    VAN05190
C----- -----
C--- GROUP 36 DEBUG PRINT-OUT SLAB AND TIME-STEP :        VAN05200
C   IZPRI<1>,IZPR2<1>,ISTPRI<1>,ISTPR2<1>    VAN05210
C----- -----
C--- GROUP 37 DEBUG SWEEP AND SUBROUTINES :          VAN05220
C   KEMU,KMAIN,KINDEX,KGEOM,KINPUT,KSODAT,KCOMP,F,KSOURCE,    VAN05230
C   KSOLV1,KSOLV2,KSOLV3,KCOMPP,KADJST,KFLUX,KSHIFT,KDIF,    VAN05240
C   KCOMPU,KCOMP,V,KCOMP,W,KCOMP,R,KWALL,KDBRH<-1>,KDBEXP,KDBMDT    VAN05250
C   KDBGEN                                         VAN05260
C----- -----
C--- GROUP 38 MONITOR, TEST, AND FLAG :            VAN05270
C   MONITR<.F.>,FLAG<.F.>,TEST<.T.>,KFLAG<1>    VAN05280
C   END OF MAINTENANCE-ONLY SECTION               VAN05290
C----- -----
C--- GROUP 39 ERROR AND RESIDUAL PRINT-OUT :       VAN05300
C   IERRP<1000>,RESREF(1,3-24)<25*x1.>,RESMAP<.F.>,    VAN05310
C   RESID(1-25)<2*x.F.,23*x.T.>,KOUTPT             VAN05320
C   RESREF(1)=WIN*xRHE                           VAN05330
C   RESREF(7)=WIN*xRESREF(1)                     VAN05340
C   RESREF(5)=WIN*xRESREF(1)*0.1                VAN05350
C   RESREF(H1)=HTOT*xRESREF(1)                  VAN05360
C   RESREF(KE)=RKEIN*xRESREF(1)                 VAN05370
C   RESREF(EP)=EPIN*xRESREF(1)                  VAN05380
C   IERRP=LSWEEP/10                            VAN05390
C   KOUTPT=LSWEEP/10                           VAN05400
C----- -----
C--- GROUP 40 SPECIAL DATA : LOGIC(1..10),INTGR(1..10),RE(21..30),    VAN05410
C   NLSP<1>,NISP<1>,NRSP<1>,SPDATA<.F.>,LSPDA(1),ISPDA(1),RSPDA(1)    VAN05420
C   USE FIRST 10 ELEMENTS OF ARRAYS LOGIC & INTGR AND 21ST    VAN05430
C   TO 30TH OF ARRAY RE FOR TRANSFERRING SPECIAL DATA FROM    VAN05440
C   SATELLITE TO GROUND, BUT IF REQUIREMENTS EXCEED THIS    VAN05450
C   PROVISION SET SPDATA = .T., AND DIMENSION ARRAYS LSPDA,    VAN05460
C   ISPDA, RSPDA ABOVE AND IN GROUND AS NEEDED, AND SET HERE    VAN05470
C----- -----
C--- GROUP 42 RESTARTS AND DUMPS : SAVEM<.F.>,RESTRT<.F.>,KINPUT    VAN05480
C   SAVEM=.TRUE.                                 VAN05490
C   BFPLT=.TRUE.                                VAN05500
C   RESTRT=.TRUE.                                VAN05510
C----- -----
C--- GROUP 43 GRAFFIC :                         VAN05520
C   GRAPHS<.F.>,ORTHOG<.T.>,ANTS,NPRT<1>,ITITL<5x4H****>    VAN05530
C--- FOR A GRAFFIC RUN, DIMENSION PHI1 & PHI2 AS FOLLOWS:    VAN05540
C   PHI1(NX*NY*NZ*NM)                          VAN05550
C   PHI2((NX+2)*(NY+2)*(NZ+2)*(NM+IBLK)) , WHERE    VAN05560
C   NM=NO. OF VARIABLES STORED + DENSITY(-IES)    VAN05570
C   IBLK=0 IF BLOCK=.FALSE.,=4 IF A 3D RUN,    VAN05580
C   =3 IF A 2D.YZ RUN.                         VAN05590
C----- -----
C   IF(IRUN.EQ.1) GO TO 900                      VAN05600
900 CONTINUE                                     VAN05610
C--- ALL RUNS                                     VAN05620
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 3 ENDS.    VAN05630
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 4 STARTS:    VAN05640

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C-----  
C WRITE GENERAL DATA ON TO THE GUSIE1.DTA TAPE, ETC...  
    IF(SPDATA) CALL WRTSPC(LSPDA,NLSP,ISPDA,NISP,RSPDA,NRSP)  
    IF(BLOCK) CALL WRTPOR(PE,PN,PH,PC,NX,NY,NZ,IPLANE)  
    IF(BFC) CALL WRTBFC(14,NBFC,XE,XW,YN,YS,ZH,ZL,  
    &ND,NX+1,NY+1,NZ+1,NZ,PRTBFC)  
C OLD PRACTICES RETAINED FOR REFERENCE:  
C     IF(SPDATA) CALL SPCDAT(IRUN)  
C     IF(BLOCK) CALL PORDAT(IRUN)  
C     IF(GRAPHS) CALL SORT(IRUN)  
C     IF(RESTRT) GO TO 902  
DO 901 INDVAR=1,25  
    IF(IFIX(FIINIT(INDVAR)+0.1).NE.10101) GO TO 901  
CALL FLDDAT(IRUN)  
GO TO 902  
901 CONTINUE  
902 CALL DATAIO(WRT,10)  
    IF(MONITR) CALL DATAIO(WRT,-6)  
999 CONTINUE  
STOP  
END  
C*** IGEN=1 SO BFCXYZ NOT REQUIRED.  
C*** COMMENT OUT BOTH VERSIONS.  
C-----  
SUBROUTINE BFCXYZ (NXP1,NYP1,NZP1)  
RETURN  
END
```

Appendix B
Ground Listing

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$DIRECTIVE**MAIN      AMI LEITNER
C      LECGRD LAST GEO. NZ=27 NY=18 LAMINAR FLOW
C      *FILE NAME: MODBFCGD.FTN
C      *INCLUDE DED SUBROUTINES: THE MODELS OF MAIN, GROUND & STRIDE.
C      *DOCUMENTATION: PHOENICS INSTRUCTION MANUAL (SPRING 1983)
C      WITH BODY-FITTED COORDINATES INSTRUCTION SUPPLEMENT
C      (SUMMER 1984).
C      *SATELLITE FILE NAME: MODSTL.FTN
C      COMMON/ISHIFT/III(57),NFMAX
C SET F-ARRAY DIMENSION AS NEEDED, & SET NFMAX ACCORDINGLY.
C FOR BFC'S ALSO SET F1-ARRAY DIMENSION AS NEEDED ,AND SET
C NF1MAX ACCORDINGLY.
COMMON/F0B/F1(10000)
COMMON/NF0B/NF1MAX
COMMON F(25000)
NFMAX=25000
NF1MAX=10000
CALL MAIN1
STOP
END

C$DIRECTIVE**GROUND
SUBROUTINE GROUND(IRN,ICHAP,ISTP,ISWP,IZED,INDVAR)
INCLUDE (CMNGUS)
INCLUDE (GUSSEQ)
C INCLUDE NMLIST
LOGICAL BFC
EQUIVALENCE (LOGIC(20),BFC)

XXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 1 STARTS:
C-----
C+++++MEANING OF SUBROUTINE ARGUMENTS:
C      IRN=RUN NUMBER; ICHAP=CHAPTER CALLED; ISTP=TIME STEP;
C      ISWP=SOLUTION SWEEP; IZED=Z-SLAB; INDX: SEE CHAPTERS BELOW.
C+++++USER-INTRODUCED VARIABLES & ARRAYS:
C      TO AVOID CONFLICT WITH VARIABLE NAMES USED IN COMMON, ALL
C      VARIABLES INTRODUCED BY THE USER SHOULD HAVE NAMES STARTING
C      WITH 'G' IF REAL, 'J' IF INTEGER, AND 'G' OR 'J' IF LOGICAL.
C      THUS GDZ(IZ) MIGHT BE A Z-INTERVAL ARRAY;
C      GW1(IY,IX) A 2-D ARRAY FOR AXIAL VELOCITY; ETC.
C      USER-GENERATED SUBROUTINES SHOULD BE NAMED CORRESPONDINGLY, EG
C      SUBROUTINE GVISC(GTEMP,GCNC,GVSC), FOR COMPUTING VISCOSITY
C      FROM CONCENTRATION & TEMPERATURE.
C+++++GROUND-TO-EARTH CONNECTING SUBROUTINES:
C      *USE GET(NAME,GARRAY,NY,NX) TO PUT VALUES OF VARIABLE NAMED
C      'NAME' INTO ARRAY 'GARRAY' DIMENSIONED GARRAY(NY,NX).
C      *USE SET(NAME,IXF,IXL,IYF,IYL,GARRAY,NY,NX) TO SET VARIABLE
C      'NAME' TO GARRAY(IY,IX) OVER THE REGION: IXF-IXL & IYF-IYL.
C      *USE PRNSLB(NAME) TO PRINT VARIABLE 'NAME' OVER X-Y PLANE.
C      *USE ADD(NAME,IXF,IXL,IYF,IYL,TYPE,CM,VM,CVAR,VVAR,NY,NX)
C          TO ADD SOURCE TO VARIABLE NAMED 'NAME' (SEE CHAPTER 5).
C      *USE READIZ(IZED) IN CHAPTERS 1, 2, 8, & 9 TO ACCESS P1,...DM
C          & VOL,...AHDZ. (SEE FOOTNOTE TO LEGALITY TABLE)
C      *USE GET1D(NAME,GARRAY,NDIM) TO PUT VARIABLE NAMED 'NAME' IN
C          ONE-D ARRAY 'GARRAY' DIMENSIONED NDIM, THUS:
C          CALL GET1D(NAME,GNX,NX) FOR XG,...DXG & DIMENSION GNX(NX);
C          CALL GET1D(NAME,GNY,NY) FOR YG,...RV & DIMENSION GNY(NY);
C          CALL GET1D(NAME,GNZ,NZ) FOR ZG,...WGRID & DIMENSION GNZ(NZ).
C+++++LEGALITY TABLE FOR USE OF EARTH-CONNECTING SUBROUTINES:
C      ENTRIES IN TABLE GIVE CHAPTERS IN WHICH SUBROUTINES CAN BE
C      USED FOR VARIABLES IN LEFT-HAND COLUMN. (SUBROUTINE
C      STRIDE IS REGARDED AS BEING IN CHAPTER 3)
C-----
C      : VARIABLE:: GET & :      SET : ADD : READIZ : GET1D :
C      :           : PRNSLB :           :       :       :       :
C      : P1 - RZ :: ALL : 6 & 7 : 5 : 1,2,8,9: NONE :
C      : P10 - RZH:: 3-7, 10-16: 3 : NONE : NONE : NONE :
C      : VOL -AHDZ:: ALL : 3 : NONE : 1,2,8,9: NONE :
C      : D1DP   :: NONE : 10 : NONE : NONE : NONE :
C      : D2DP   :: NONE : 11 : NONE : NONE : NONE :
C      : MUL,MU1H :: 5,13-16: 12 : NONE : NONE : NONE :
C      : EXCO(L,H):: NONE : 13 : NONE : NONE : NONE :
C      : CFP    :: 5   : 14 : NONE : NONE : NONE :

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C      :MDT    ::   5   :  15   :  NONE  :  NONE  :  NONE  :  VAN00730
C      :HST1,HST2:: 5 & 15  :  16   :  NONE  :  NONE  :  NONE  :  VAN00740
C      :XG -WGRID::  NONE  :  NONE  :  NONE  :  NONE  :  ALL   :  VAN00750
C      -----
C      NOTES ON ABOVE TABLE:
C      *IN CHAPTERS 1, 2, 8, & 9 VARIABLES P1...DM & GEOMETRY
C      VOL...AHDZ CAN BE ACCESSED BUT ONLY IN CONJUNCTION WITH
C      USE OF READIZ, THUS:
C      DO 1 IZED=1,NZ
C      CALL READIZ(IZED)
C      1 CALL GET(... AS REQUIRED...)
C      *GEOMETRY ACCESSED BY READIZ IS THAT AT INITIAL TIME.
C      *D1DP & D2DP ONLY ACCESSIBLE IN UNSTEADY FLOWS.
C      ++++++GROUND SERVICE SUBROUTINES:
C      *USE CONTUR(NAME,IPLANE,ILOC,NINT,I1,I2,J1,J2,GARRAY,NDIM) FOR
C      LINE-PRINTER PLOTS OF CONTOURS. 'NAME' = U1,...C4;
C      'IPLANE'= XPLANE, YPLANE, OR ZPLANE; ILOC SETS IX, IY, OR
C      IZ LOCATION OF IPLANE; I1, I2, J1, & J2 SET FIRST & LAST
C      CELLS IN HORIZ. & VERT. ON PLOT; GARRAY IS 1-D WORKING ARRAY
C      OF DIMENSION NX*NY, NX*NZ, OR NY*NZ DICTATED BY IPLANE; &
C      NDIM SETS VALUE OF DIMENSION OF GARRAY.
C      *USE FLD2DA(TITLE,GARRAY,NY,NX) TO PRINT ANY ARRAY DIMENSIONED
C      GARRAY(NY,NX); SET 'TITLE' TO REQUIRED NAME ( 4 HOLLERITH
C      CHARACTERS ONLY).
C      *USE FLD3DA(TITLE,GARRAY,NX,NY,NZ,IPLANE,ILOC) TO PRINT ANY
C      ARRAY DIMENSIONED GARRAY(NX,NY,NZ) IN PLANE SPECIFIED BY
C      'IPLANE' & 'ILOC' AS FOR CONTUR ABOVE; SET 'TITLE' AS FOR
C      FLD2DA.
C      VARIABLE NAMES FOR USE IN GROUND:
COMMON/TYPE/CELL,EAST,WEST,NORTH,SOUTH,HIGH,LOW,VOLUME,WALL
COMMON/VAR/PP,U1,U2,V1,V2,W1,W2,R1,R2,RS,
&KE,EP,H1,H2,H3,C1,C2,C3,C4,RX,RY,RZ,S1,S2
COMMON/VAROLD/P10,PP0,U10,U20,V10,V20,W10,W20,R10,R20,RS0,
&KE0,EPO,H10,H20,H30,C10,C20,C30,C40,RX0,RY0,RZ0,S10,S20
COMMON/VARLOW/P1L,PPL,U1L,U2L,V1L,V2L,W1L,W2L,R1L,R2L,RSL,
&KEL,EPL,H1L,H2L,H3L,C1L,C2L,C3L,C4L,RXL,RYL,RZL,S1L,S2L
COMMON/VARHI/P1H,PPH,U1H,U2H,V1H,V2H,W1H,W2H,R1H,R2H,RSH,
&KEH,EPH,H1H,H2H,H3H,C1H,C2H,C3H,C4H,RXH,RYH,RZH,S1H,S2H
COMMON/GMTRY/VOL,VOLO,AEAST,ANORTH,AHIGH,AEDX,ANDY,AHDZ
COMMON/PROP/D1,D2,D1DP,D2DP,MUI,MUILAM,EXCO,CFP,MDT,HST1,HST2
COMMON/PRPOLD/D10,D20
COMMON/PRPLOW/D1L,D2L,EXCOL
COMMON/PRPHI/D1H,D2H,MU1H,EXCOH
COMMON/VARNX/XG,XU,DXU,DXG
COMMON/VARNY/YG,YV,DYV,DYG,R,RV
COMMON/VARNZ/ZG,ZW1,DZW,DZG,WGRID
COMMON/GDMSCI/XPLANE,YPLANE,ZPLANE,ITNO
COMMON/GDMSC1/LSLAB,MSLAB,HSLAB,LAMMU
REAL NORTH,LOW
INTEGER P1,PP,U1,U2,V1,V2,W1,W2,R1,R2,RS,
&EP,H1,H2,H3,C1,C2,C3,C4,RX,RY,RZ,S1,S2
INTEGER P10,PP0,U10,U20,V10,V20,W10,W20,R10,R20,RS0,
&EPO,H10,H20,H30,C10,C20,C30,C40,RX0,RY0,RZ0,S10,S20
INTEGER P1L,PPL,U1L,U2L,V1L,V2L,W1L,W2L,R1L,R2L,RSL,
&EPL,H1L,H2L,H3L,C1L,C2L,C3L,C4L,RXL,RYL,RZL,S1L,S2L
INTEGER P1H,PPH,U1H,U2H,V1H,V2H,W1H,W2H,R1H,R2H,RSH,
&EPH,H1H,H2H,H3H,C1H,C2H,C3H,C4H,RXH,RYH,RZH,S1H,S2H
INTEGER VOL,VOLO,AEAST,ANORTH,AHIGH,AEDX,ANDY,AHDZ
INTEGER D1,D1DP,D2,D2DP,EXCO,CFP,HST1,HST2
INTEGER D10,D20,D1L,D2L,EXCOL,D1H,D2H,EXCOH
INTEGER XG,XU,DXU,DXG,YG,YV,DYV,DYG,R,RV,ZG,ZW1,DZW,
&DZG,WGRID
INTEGER XPLANE,YPLANE,ZPLANE
LOGICAL LSLAB,MSLAB,HSLAB,LAMMU,LSPDA
EQUIVALENCE (M1,R1),(M2,R2)
C      SATLIT-EQUIVALENT IRUN:
EQUIVALENCE (IRUN,INTGR(11))
XXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 1 ENDS.
XXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 1 STARTS:
C      ARRAYS ( DIMENSIONED NY,NX ) FOR USE WITH 'ADD':
DIMENSION CVAR(1,1),VVAR(1,1),CM(1,1),VM(1,1),ZERO(1,1)
DIMENSION GP(30,1),GH(30,1),GD(30,1),GV(30,1),GW(30,1)

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1 ,GMACH(30,1),GTEMP(30,1),GVISC(30,1),GWH(30,1),GWM(30,1)          VAN01450
2 ,GKE(30,1),GC3(30,1),GYC(30,1),GXX(30,1),GYY(30,1),GZZ(30,1)        VAN01460
C   SPECIAL-DATA ARRAYS DIMENSIONED & DIMENSION VALUES SET HERE:        VAN01470
C   DIMENSION LSPDA(1),ISPDA(1),RSPDA(1)                                     VAN01480
C   USER PLACES HIS VARIABLES, ARRAYS, EQUIVALENCES ETC. HERE.           VAN01490
C   EQUIVALENCE (RAIR,RE(21)),(GAMA,RE(22)),(GSWP,RE(23)),                VAN01500
C   1(GPR,RE(24)),(GTW,RE(25)),(GEMU1,RE(26)),(JEMU1,INTGR(1))           VAN01510
C   DATA NLSP,NISP,NRSP/1,1,1/                                              VAN01520
C   DATA CVAR,VVAR,CM,VM,ZERO/5*0.0/                                         VAN01530
C   USER PLACES HIS DATA STATEMENTS HERE.                                     VAN01540
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 1 ENDS.                         VAN01550
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 2 STARTS:                   VAN01560
C   PLEASE DO NOT ALTER, OR RE-SET, ANY OF THE REMAINING                  VAN01570
C   STATEMENTS OF THIS SECTION.                                             VAN01580
C   DATA NUMCH4 / 0 /
C     IF(SPDATA)
C       &CALL RDSPC(IRN,INTGR(12),LSPDA,NLSP,ISPDA,NISP,RSPDA,NRSP)
C       CALL GRDUTY(IRN,ICHAP,IZED,INDVAR)
C       IF(BFC) CALL BFCGRD(IRN,ICHAP,ISWP,IZED,INDVAR)
C         IF(ICHAP.EQ.-5) GO TO 10
C         IF(ICHAP.LE.0.OR.ICHAP.GT.16) RETURN
C         GO TO (100,200,300,4999,500,600,700,800,900,1000,1100,1200,
C &1300,1400,1500,1600),ICHAP
C         RETURN
4999 NUMCH4= NUMCH4 + 1
C       IF (MOD(NUMCH4,2).EQ.1) GO TO 400
C       RETURN
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXX STANDARD SECTION 2 ENDS.                     VAN01690
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXX USER SECTION 2 STARTS:                         VAN01700
C-----C
C   CHAPTER 0: MODIFY SATLIT DATA, AT START OF EACH IRN.                   VAN01710
C-----C
10 CONTINUE
C     IF(.NOT.NAMLST) RETURN
C     IF(IRN.EQ.NRUN) DATFIL=.FALSE.
C--- READ SATLIT DATA NAMELIST HERE
C     CALL WRIT40(40HENTER NAMELIST DATA FOR GROUPS 1 TO 24 )
C     READ(20,G1G24)
C     CALL WRIT40(40HENTER NAMELIST DATA FOR GROUPS 25 TO 42 )
C     READ(20,G25G42)
C     RETURN
C-----C
C   CHAPTER 1: CALLED AT THE START OF EACH TIME STEP.
C   SET 'DT' HERE WHEN TLAST SET NEGATIVE IN BLOCK DATA.
C   'ATIME + DT' GIVES THE END TIME OF THE CURRENT TIME STEP.
C   NOT ACCESSED IF STEADY,OR PARABOLIC.
C-----C
100 CONTINUE
C     RETURN
C-----C
C   CHAPTER 2: CALLED AT THE START OF EACH SWEEP.
C-----C
200 CONTINUE
C     RETURN
C-----C
C   CHAPTER 3: CALLED AT THE START OF EACH SLAB;
C   NOT ACCESSED IF PARABOLIC, BUT 'STRIDE' IS.
C-----C
300 CONTINUE
C     RETURN
C-----C
C   CHAPTER 4: CALLED AT THE START OF EACH RE-CALCULATION OF
C   VARIABLES P1,...C4 AT CURRENT SLAB. ITNO= ITERATION NUMBER.
C-----C
400 CONTINUE
C     RETURN
C-----C
C   CHAPTER 5: GROUND CALLED WHEN SOURCE TERM IS COMPUTED.
C   INDX VAR GIVES DEPENDENT VARIABLE IN QUESTION IE. U1,...C4.
C   TO ADD SOURCE TO DEPENDENT VARIABLE C1(SAY) FOR IX=IXF,IXL
C   AND IY=IYF,IYL INSERT STATEMENT:
C   IF(INDVAR.EQ.C1)

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&CALL ADD(INDVAR,IXF,IXL,IYF,IYL,TYPE,CM,VM,CVAR,VVAR,NY,NX)
  NOTES ON 'ADD':
  *SOURCE= (CVAR(IY,IX)+AMAX1(0.0,MASFLO))*(VVAR(IY,IX)-PHI),
    WHERE 'PHI' IS IN-CELL VALUE OF VARIABLE IN QUESTION.
  *'MASFL0'= CM(IY,IX)*(VM(IY,IX)-P),
    WHERE 'P' IS THE IN-CELL PRESSURE.
  *FOR INDX= M1, OR =M2, SOURCE ADDED IS 'MASFL0' ONLY,
    EXCEPT FOR ONEPHS=.F. & MASFLO < 0.0 (IE. OUTFLOW) WHEN
    CM(IY,IX) IS MULTIPLIED BY R1*D1 (FOR M1) & R2*D2 (FOR M2).
  *BOTH 'CVAR' & 'CM' ARE MUTLIPLIED BY CELL-GEOMETRY QUANTITY
    DICTATED BY SETTING OF 'TYPE' (=CELL, EAST AREA,..VOLUME).
  *TYPE-SPECIFIED AREAS ARE CALCULATED AS IF BLOCKAGE ABSENT,
    BUT 'VOLUME' WITH ACCOUNT FOR ITS PRESENCE.
  *FOR ALL SOLVED VARIABLES, INCLUDE DING M1 (& M2 WHEN ONEPHS=F),
    IF 'CM'> 0.0 CALL 'ADD'; FOR M1 & M2 ALTHOUGH 'CVAR' & 'VVAR'
    HAVE NO SIGNIFICANCE THEY MUST BE ENTERED AS ARGUMENTS.
  *'CVAR', 'VVAR', 'CM' & 'VM' MUST BE DIMENSIONED NY,NX.

C-----500 CONTINUE
C-----RETURN

C-----CHAPTER 6: CALLED AT THE END OF EACH VARIABLE-RECALCULATION
C-----CYCLE COMMENCED AT CHAPTER 4. ITNO = ITERATION NUMBER.

C-----600 CONTINUE
C-----RETURN

C-----CHAPTER 7: CALLED AT END OF EACH SLAB-WISE CALCULATION.

C-----700 CONTINUE
IF(FLOAT(ISWP).LT.GSWP) RETURN
CALL GET(P1,GP,NY,NX)
CALL GET(H1,GH,NY,NX)
CALL GET(D1,GD,NY,NX)
CALL GET(V1,GV,NY,NX)
CALL GET(W1,GW,NY,NX)
CALL GET(KE,GKE,NY,NX)
CALL GET1D(YG,GYG,NY)
CALL GRED1(39,IZED,GYG,NY,NX)
CALL GRED3(57,IZED,GXX,GYY,GZZ,NY,NX)
GCP=RAIR/(1.-1/GAMA)
DO 701 I=1,NY
  GSON=SQRT(GAMA*GP(I,1)/GD(I,1))
  GAV=SQRT(GV(I,1)**2+GW(I,1)**2)
  GMACH(I,1)=GAV/GSON
  701 GTEMP(I,1)=GP(I,1)/GD(I,1)/RAIR
C 701 GTEMP(I,1)=(GH(I,1)-GW(I,1)**2/2.-GV(I,1)**2/2.)/GCP
  CALL SET(C1,1,NX,1,NY,GMACH,NY,NX)
  CALL SET(C2,1,NX,1,NY,GTEMP,NY,NX)
C-----CALCULATE DY1 CF ST H(CONVECTIVE COEF.) Q TAU TR
  IF(JEMUI.NE.2) GOTO 702
C-----TURBULENT VALUES
C7   GCF=2./GW(NY,1)**2*GKE(1,1)/3.33*GD(1,1)/GD(NY,1)
  GCF=GCF*GD(NY,1)/GD(1,1)*GTEMP(NY,1)/GTEMP(1,1)*GP(1,1)/GP(NY,1)
  GST=GCF/2./GPR**.666
  GHH=GD(NY,1)*GCP*GW(NY,1)*GST
  GR=GPR**.333
  GTR=GTEMP(NY,1)*(1.+GR*(GAMA-1.)/2.*GMACH(NY,1)**2)
  C 1(1.+(GAMA-1.)/2.*GMACH(NY,1)**2)
  GQ=GHH*(GTR-GTW)
  GOTO 703
C-----LAMINAR VALUES
  702 CONTINUE
  IF(JEMUI.EQ.-1) GEMUI=GVISCC(1,1)
  GQ=GEMUI/GPR*(GH(1,1)-GTW*GCP)/GYG(1,1)
  GR=GPR**.5
  GTR=GTEMP(NY,1)*(1.+GR*(GAMA-1.)/2.*GMACH(NY,1)**2)
  C 1(1.+(GAMA-1.)/2.*GMACH(NY,1)**2)
  GHH=GQ/(GTR-GTW)
  GST=GHH/(GD(NY,1)*GW(NY,1)*GCP)
  GTAU=GEMUI*GW(1,1)/GYG(1,1)
  GCF=GTAU*2./(GD(NY,1)*GW(NY,1)**2)

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703 GC3(1,1)=GYG(1,1)          VAN02890
    GC3(2,1)=GCF             VAN02900
    GC3(3,1)=GST             VAN02910
    GC3(4,1)=GCF/2./GST      VAN02920
    GC3(5,1)=GHH             VAN02930
    GC3(6,1)=GQ              VAN02940
    GC3(7,1)=GTAU            VAN02950
    GC3(8,1)=GTR              VAN02960
    GC3(9,1)=GTR-GTW         VAN02970
    GC3(10,1)=GD(NY,1)*GW(NY,1)*GZZ(1,1)/GEMU1  VAN02980
    GC3(11,1)=GZZ(1,1)        VAN02990
    GC3(12,1)=GEMU1           VAN03000
    GC3(13,1)=GD(NY,1)*GW(NY,1)*GYG(1,1)/GEMU1*SQRT(ABS(GCF/2.))  VAN03010
    CALL SET(C3,1,NX,1,NY,GC3,NY,NX)          VAN03020
    RETURN                           VAN03030
C-----VAN03040
C-----CHAPTER 8: CALLED AT THE END OF EACH SWEEP;  VAN03050
C-----NOT ACCESSED IF PARABOLIC.               VAN03060
C-----VAN03070
800 CONTINUE          VAN03080
    RETURN                         VAN03090
C-----VAN03100
C-----CHAPTER 9: CALLED AT THE END OF EACH TIME STEP;  VAN03110
C-----NOT ACCESSED IF PARABOLIC.               VAN03120
C-----VAN03130
900 CONTINUE          VAN03140
    RETURN                         VAN03150
C-----VAN03160
C-----CHAPTER 10: SET PHASE 1 DENSITY HERE WHEN IRH01=-1 IN DATA.  VAN03170
SET CURRENT-Z 'SLAB' DENSITY, D1, IF MSLAB=.T.;  VAN03180
EG. IF(MSLAB) CALL SET(D1,1,NX,1,NY,JD1,NY,NX).  VAN03190
SET NEXT LARGER-Z 'SLAB' DENSITY, D1H, IF HSLAB=.T. & PARAB=F  VAN03200
EG. IF(HSLAB) CALL SET(D1H,1,NX,1,NY,JD1H,NY,NX).  VAN03210
SET D(LN(D1))/DP (IE. D1DP) FOR UNSTEADY FLOW,  VAN03220
EG. IF(MSLAB) CALL SET(D1DP,1,NX,1,NY,JD1DP,NY,NX).  VAN03230
C-----VAN03240
1000 CONTINUE          VAN03250
    IF (MSLAB) GO TO 101
    JP1=P1H          VAN03260
    JH1=H1H          VAN03270
    JD1=D1H          VAN03280
    JW1=W1H          VAN03290
    JV1=V1H          VAN03300
    GO TO 102          VAN03310
101 JP1=P1          VAN03320
    JH1=H1          VAN03330
    JD1=D1          VAN03340
    JW1=W1          VAN03350
    JV1=V1          VAN03360
    VAN03370
102 CALL GET(JP1,GP,NY,NX)          VAN03380
    CALL GET(JH1,GH,NY,NX)          VAN03390
    CALL GET(JW1,GW,NY,NX)          VAN03400
    CALL GET(JV1,GV,NY,NX)          VAN03410
    IF(IZED.EQ.1) GOTO 105          VAN03420
    IF(IZED.EQ.NZ) GOTO 109          VAN03430
C-----IZED=2,NZ-1          VAN03440
    DO 103 IX=1,NX          VAN03450
    DO 103 IY=1,NY          VAN03460
    IF(HSLAB) GOTO 104          VAN03470
    GWA=(GW(IY,IX)+GWM(IY,IX))/2.  VAN03480
    GWM(IY,IX)=GW(IY,IX)          VAN03490
    GOTO 115          VAN03500
104 GWA=(GW(IY,IX)+GWH(IY,IX))/2.  VAN03510
    GWH(IY,IX)=GW(IY,IX)          VAN03520
115 GHS=GH(IY,IX)-(GWA**2+GV(IY,IX)**2)/2.  VAN03530
    IF(GHS.LE.1.E5) GHS=1.E5          VAN03540
    103 GD(IY,IX)= GP(IY,IX)/(1-1/GAMA)/GHS  VAN03550
    GOTO 113          VAN03560
C-----IZED=1          VAN03570
105 DO 106 IX=1,NX          VAN03580
    DO 106 IY=1,NY          VAN03590
    GHS=GH(IY,IX)-(GW(IY,IX)**2+GV(IY,IX)**2)/2.  VAN03600

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        IF(GHS.LE.1.E5) GHS=1.E5          VAN03610
        GD(IY,IX)= GP(IY,IX)/(1-1/GAMA)/GHS  VAN03620
        IF(HSLAB) GOTO 107                VAN03630
        GWM(IY,IX)=GW(IY,IX)              VAN03640
        GOTO 106                          VAN03650
107   GWH(IY,IX)=GW(IY,IX)            VAN03660
106   CONTINUE                         VAN03670
        GOTO 113                          VAN03680
C-----IZED=NZ                         VAN03690
109   DO 110 IX=1,NX                  VAN03700
        DO 110 IY=1,NY                  VAN03710
        IF(HSLAB) GOTO 111              VAN03720
        GHS=GH(IY,IX)-(GWM(IY,IX)**2+GV(IY,IX)**2)/2.  VAN03730
        IF(GHS.LE.1.E5) GHS=1.E5      VAN03740
        GWM(IY,IX)=GW(IY,IX)          VAN03750
        GOTO 112                          VAN03760
111   GHS=GH(IY,IX)-(GWH(IY,IX)**2+GV(IY,IX)**2)/2.  VAN03770
C     IF(GHS.LE.1.E5) GHS=1.E5      VAN03780
        GWH(IY,IX)=GW(IY,IX)          VAN03790
112   GD(IY,IX)= GP(IY,IX)/(1-1/GAMA)/GHS  VAN03800
110   CONTINUE                         VAN03810
C-----                         VAN03820
113   CONTINUE                         VAN03830
        CALL SET(JD1,1,NX,1,NY,GD,NY,NX)  VAN03840
        RETURN                           VAN03850
C-----                         VAN03860
C     CHAPTER 11: SET PHASE 2 DENSITY HERE WHEN IRHO2=-1 IN DATA.  VAN03870
C     SET CURRENT-Z 'SLAB' DENSITY, D2, IF MSLAB=.T.,          VAN03880
C     EG. IF(MSLAB) CALL SET(D2,1,NX,1,NY,GD2,NY,NX).  VAN03890
C     SET NEXT LARGER-Z 'SLAB' DENSITY, D2H, IF HSLAB=.T. & PARAB=F  VAN03900
C     EG. IF(HSLAB) CALL SET(D2H,1,NX,1,NY,GD2H,NY,NX).  VAN03910
C     SET D(LNC(D2))/DP FOR UNSTEADY FLOW,          VAN03920
C     EG. IF(MSLAB) CALL SET(D2DP,1,NX,1,NY,GD2DP,NY,NX).  VAN03930
C-----                         VAN03940
1100  CONTINUE                         VAN03950
        RETURN                           VAN03960
C-----                         VAN03970
C     CHAPTER 12: SET PHASE 1 VISCOSITY HERE WHEN IEMU1=-1 IN DATA.  VAN03980
C     SET CURRENT-Z 'SLAB' VISCOSITY (MU1), IF MSLAB=.T.,          VAN03990
C     EG. IF(MSLAB) CALL SET(MU1,1,NX,1,NY,GVISC,NY,NX).  VAN04000
C     SET NEXT LARGER-Z 'SLAB' VISC. (MU1H), IF HSLAB=.T. & PARAB=F  VAN04010
C     EG. IF(HSLAB) CALL SET(MU1H,1,NX,1,NY,GVSCH,NY,NX).  VAN04020
C-----                         VAN04030
C     CHAPTER ALSO ACCESSED WHEN EMULAM=-1.0 IN DATA, SO THAT THE  VAN04040
C     LAMINAR VISCOSITY WHICH APPEARS IN WALL FUNCTIONS & IN THE  VAN04050
C     KE-EP TURBULENCE MODEL (IEMU1=2) MAY BE SET NON-CONSTANT.  VAN04060
C     SET CURRENT-Z 'SLAB' VALUE (MUILAM) WHEN LAMMU=.T.,          VAN04070
C     EG. IF(LAMMU) CALL SET(MUILAM,1,NX,1,NY,GVSCL,NY,NX).  VAN04080
C-----                         VAN04090
1200  CONTINUE                         VAN04100
        GCP=RAIR/(1.-1/GAMA)          VAN04110
        IF (HSLAB) GOTO 122           VAN04120
        CALL GET(H1,GH,NY,NX)          VAN04130
        CALL GET(W1,GW,NY,NX)          VAN04140
        CALL GET(V1,GV,NY,NX)          VAN04150
        GOTO 123                          VAN04160
122   CALL GET(H1H,GH,NY,NX)          VAN04170
        CALL GET(W1H,GW,NY,NX)          VAN04180
        CALL GET(V1H,GV,NY,NX)          VAN04190
123   CONTINUE                         VAN04200
        DO 121 IX=1,NX                  VAN04210
        DO 121 IY=1,NY                  VAN04220
        GTMP=(GH(IY,IX)-GW(IY,IX)**2/2.-GV(IY,IX)**2/2.)/GCP  VAN04230
        IF(GTMP.LT.150.) GTMP=150.          VAN04240
121   GVISC(IY,IX)=1.716E-05*(GTMP/273.)*0.666          VAN04250
C121   IF(GVISC(IY,IX).LE..8E-5) GVISC(IY,IX)=.8E-5          VAN04260
        IF (MSLAB) CALL SET(MU1,1,NX,1,NY,GVISC,NY,NX)  VAN04270
        IF (HSLAB) CALL SET(MU1H,1,NX,1,NY,GVISC,NY,NX)  VAN04280
        IF (LAMMU) CALL SET(MUILAM,1,NX,1,NY,GVISC,NY,NX)  VAN04290
        RETURN                           VAN04300
C-----                         VAN04310
C     CHAPTER 13: SET EXCHANGE COEFFICIENT (E.C.) FOR VARIABLE  VAN04320

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C INDVAR WHEN SIGMA(INDVAR)=-1.0 IN DATA.  
C SET CURRENT-Z 'SLAB' E.C. (EXCO) IF MSLAB=.T.,  
C EG. IF(MSLAB) CALL SET(EXCO,1,NX,1,NY,GEXCO,NY,NX).  
C SET NEXT SMALLER-Z 'SLAB' E.C. (EXCOL) IF LSLAB=.T.,  
C EG. IF(LSLAB) CALL SET(EXCOL,1,NX,1,NY,GEXCOL,NY,NX).  
C SET NEXT LARGER-Z 'SLAB' E.C. (EXCOH) IF HSLAB=.T.,  
C EG. IF(HSLAB) CALL SET(EXCOH,1,NX,1,NY,GEXCOH,NY,NX).  
C NOTE: FOR MSLAB, INDVAR=U1,..C4; FOR LSLAB, INDVAR=U1L,..C4L  
C & FOR HSLAB, INDVAR=U1H,..C4H. IF PARAB=.T. SET MSLAB ONLY.  
C-----  
1300 CONTINUE  
RETURN  
C-----  
C CHAPTER 14: SET INTER-PHASE FRICTION COEFFICIENT (CFP) HERE  
C WHEN ICFIP = -1 IN DATA; ITS UNITS = FORCE / (CELL * RELATIVE  
C SPEED OF PHASES).  
C-----  
1400 CONTINUE  
RETURN  
C-----  
C CHAPTER 15: SET INTER-PHASE MASS-TRANSFER RATE PER CELL (MDT)  
C HERE WHEN IMDOT = -1 IN DATA.  
C-----  
1500 CONTINUE  
RETURN  
C-----  
C CHAPTER 16: SET HERE PHASE 1 & 2 SATURATION ENTHALPIES  
C (HST1 & HST2) WHEN IHSAT = -1 IN DATA.  
C-----  
1600 CONTINUE  
RETURN  
END
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